Exploring benefits and challenges when implementing automation in a manufacturing company

K Nkogatse

orcid.org/0009-0007-4872-0102

Mini-dissertation accepted in partial fulfilment of the requirements for the degree *Master of Business Administration* at the North-West University

Supervisor: Dr JA Jordaan

Graduation: June 2026

DECLARATION

I hereby declare that the assignment submitted herewith to the North-West University in partial fulfilment of the requirements for the Master of Business Administration (MBA) degree is my own original work and all sources have been attributed as required by academic conventions, and that the dissertation has not been submitted for a different qualification. It has been text-edited in accordance with professional communication standards and has not been previously submitted to any other institution for evaluation purposes.

Khutso Nkogatse

28 November 2025

DEDICATION

I would like to dedicate this dissertation to my family, whose unending love, support, and belief in me have helped me through all the stages of this academic endeavour. I owe my profoundest gratitude to my parents (Ouma & Phillip Nkogatse), who taught me the lessons of discipline, resilience, and hard work. Your support and sacrifices have formed the basis for my career and academic interests. Thank you to my partner and loved ones for your patience, emotional strength, and constant reassurance at times when the burden of this programme seemed great. Your support and friendliness were my driving power and gave me the strength to continue. I would also like to dedicate this work to the several men and women in the manufacturing sector in South Africa whose lived experiences, insights, and day-to-day contributions are the wheels of industry, especially the employees of Komatsu. This research topic was inspired by their dedication to operational excellence, especially in environments prone to technological and infrastructural challenges. The dissertation is a testament to their hard work and perseverance, and I hope the results will be insightful in enhancing productivity and innovation, as well as shaping the future of work in our country.

PREFACE

This dissertation is presented to fulfil in part the requirements of a Magister in Business Administration at the North-West University. It is the culmination of a rigorous academic pursuit of the advantages and problems of automation in the South African manufacturing industry. The rationale for the study was the increasing need for organisations in developing economies to upgrade their production systems, enhance their competitiveness, and respond effectively to the global industrial changes driven by the Fourth Industrial Revolution.

During this research, I had the privilege of interacting with industry professionals, my academic supervisors, and fellow students, who provided me with valuable knowledge and advice. Their views enhanced my knowledge on both theoretical and practical aspects of automation in the mining equipment manufacturing industry. The writing below indicates my desire to contribute to the literature on productivity enhancement, automation preparedness, and organisational-level performance in the manufacturing environment of South Africa.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to everyone who has helped me with this research process. I would like to express my sincere gratitude to Dr J. Jordaan, my supervisor, for his support, constructive criticism, and encouragement, which have reinforced the quality and academic rigour of this dissertation. Your enthusiasm to do your best has influenced my academic life and contributed to my knowledge of research methodology and critical analysis.

I would like to thank the management and workers of the involved manufacturing company not only for allowing me to be part of their world but also for voluntarily sharing their experience, perceptions, and understanding of automation and productivity. Your cooperation and openness have made this study possible.
To my fellow students in the MBA programme, I would like to say that I have really enjoyed this journey, which was challenging but worthwhile, due to the valuable discussions, teamwork, and encouragement. Your encouragement created a learning environment that promoted growth, professionalism, and intellectual curiosity.

Lastly, I would like to acknowledge my family and friends who have consistently supported me. Your emotional and moral support helped me through the points of pressure and uncertainty, and I am grateful.

ABSTRACT

The manufacturing industry in South Africa is still experiencing the structural, infrastructural, and technological issues that have been affecting its competitiveness, productivity, and sustainability. With the acceleration of automation and Fourth Industrial Revolution (4IR) technologies reinventing global production norms, the slower uptake of advanced automation in South Africa has increased competition between local and international producers. This paper examines the correlation between increased automation and productivity in one of the large mining equipment manufacturing firms in the East Rand.

The study employed a quantitative research design, with a structured questionnaire administered to employees across departments. One hundred sixty-nine accepted responses were analysed using descriptive statistics, composite scale scores, and correlation methods. The results indicate moderate scores in the adoption of automation and in overall awareness of productivity amongst the workers. Nevertheless, no statistically significant relationship was found between the automation measures and perceived productivity, suggesting that automation within the organisation may be poorly distributed, poorly integrated, or inadequately communicated. Other external factors, such as energy insecurity, infrastructural limitations, and intermittent digital access, also became potential moderating variables.

The research can be used to learn about automation preparedness in the South African manufacturing industry and to emphasise a comprehensive approach that incorporates technology, skills training, change management, and infrastructure upgrades. Practical advice is provided to help organisations in the changing industrial environment to modernise their production systems, workforce, and productivity outcomes.

Keywords: Automation, Productivity, Manufacturing Industry, Industry 4.0, Technology, Mining Equipment, Organisational Performance, South Africa.

LIST OF ABBREVIATIONS

4IR	Fourth Industrial Revolution
AI	Artificial Intelligence
ARDL	Autoregressive Distributed Lag Model
DOLS	Dynamic Ordinary Least Squares
FMOLS	Fully Modified Ordinary Least Squares
GDP	Gross Domestic Product
ICT	Information and Communication Technology
IoT	Internet of Things
I4.0	Industry 4.0
MVA	Manufacturing Value Added
NWU	North-West University
OEE	Overall Equipment Effectiveness
R&D	Research and Development
SMEs	Small and Medium-Sized Enterprises
SME	Structural Equation Modelling
SPSS	Statistical Package for the Social Sciences
VECM	Vector Error Correction Model
WEF	World Economic Forum

Table of Contents

LIST OF FIGURES (HEADING)

CHAPTER 1 OVERVIEW

1.1 Introduction

Automation has emerged as a core driver of industrial progress, underlying productivity, efficiency, and competitiveness in globalised manufacturing. Across developed economies, the coupling of automation with the 4IR's frontier technologies has recast the production system into a highly flexible, data-driven ecosystem. Such ecosystems have delivered dividends in reduced costs, improved quality, and enhanced responsiveness to evolving consumer demands (Codera Analytics, 2023). In the South African context, take-up has been much more subdued, primarily due to infrastructural shortfalls, the need for expensive capital investment, and organisational resistance to change. This equates to a competency shortfall of critical dimensions relative to foreign competitors, particularly as the country endeavours to reposition its industrialised base amid escalating global tensions.

South Africa's manufacturing industry contributes 12% to GDP and 12% to formal employment but has been losing competitiveness since the 1980s (IDC, 2019). Chronic structural bottlenecks, unreliable power supply, deteriorating transport infrastructure, and water constraints actively discourage manufacturing activity (SAICE, 2022). Coupled with compounding digital divides and extensive data, the integration of high-end digital manufacturing systems proves inconvenient (International Trade Administration, 2024). In this scenario, greater automation, particularly through advances in robotics, machine learning, and the Internet of Things (IoT), could reindustrialise South Africa's industrial base by eliminating these systemic barriers.

Productivity, as conventionally measured as input-to-output efficiency, remains the most significant source of industrial competitiveness (U.S. Bureau of Labor Statistics, 2025). South African manufacturing productivity is eroded by obsolete equipment, high downtime, and high input costs. Greater automation eliminates these inefficiencies by optimising process flow, reducing error rates, and improving throughput. For example, Overall Equipment Effectiveness (OEE), one of the basic productivity metrics, can be significantly improved through real-time monitoring systems that detect equipment downtime, energy losses, and quality losses (The Reserve Bank of Australia, 2025). In addition, flexible automation systems enable producers to switch between product lines quickly, allowing firms to service heterogeneous markets without the long delays that characterise traditional batch production.

Despite such advantages, there are challenges. The significant upfront capital outlays restrict take-up by small and medium-sized producers, whilst the lack of skilled technical labour constrains successful rollout. Studies suggest that without targeted investment in workers' reskilling and upskilling, automation will substitute for, rather than augment productivity (World Economic Forum, 2023:24). Governments and businesses, therefore, must follow a balanced approach, investing simultaneously in both automation equipment and human capital development.

The South African example illustrates that automation is not simply a technological question but a challenge of systemic change encompassing infrastructure, capabilities, and industrial policy. Ngepah *et al*. (2024:2) found that Industry 4.0 adoption in South Africa has multifaceted impacts, with some evidence suggesting an inverse correlation with value-added manufacturing when adoption is fragmented or partial. This highlights the need for comprehensive approaches that integrate automation with energy reliability, ICT improvements, and regulatory changes. International best practices are helpful in this respect. Hyper-automation systems in advanced economies integrate artificial intelligence, robotics, and analytics to optimise processes at scale (Haleem *et al*., 2021:2). Such benchmarks emphasise the imperative for South Africa to adopt multi-technology approaches rather than piecemeal interventions.

1.2 Problem statement

Although the world is rapidly automating and transitioning to Industry 4.0, productivity results linked to automation implementations are still unequal, especially in the developing economies like South Africa. Although global literature tends to document a positive effect of automation on productivity, South African manufacturing company empirical data show a mixed outcome with some studies showing that there is little or no significant effect on productivity. Such inconsistencies are often explained by the contextual factors, including infrastructural limitations, skills deficit, partial integration of systems, and organisational preparedness.

In the South African mining equipment manufacturing industry, automation has been at different levels, but it is not clear whether adoption of further automation is coupled with better productivity at the firm level. The available research tends to be based on macro-economic parameters or industry related statistics and may not be a rich source of information on perceptions of automation and productivity at the individual employee level. Subsequently, no specific empirical study investigates whether adoption of automation is associated with a perceived productivity gain in operational settings that are typified by energy insecurity, infrastructural constraints, and workforce transition issues.

The gap in the research discussed in this study is thus that there has been no clear empirical evidence to determine the relationship between automation adoption and perceived productivity in a South African based mining equipment manufacturing firm. The relationship has been deemed important in understanding how managerial decisions are made and how investments made in automation in the future and how technological adoption is coordinated to the ability of organisation and the work force.

1.3 Research question

What is the effect of enhanced automation on the level of productivity and competitiveness in the South African mining systems manufacturing industry?

1.4 Study objectives

1.4.1 Primary objective

To determine the relationship between automation adoption and perceived productivity within a South African mining equipment manufacturing organisation.

1.4.2 Secondary objectives

- To understand the degree of automation adoption in the few departments that are chosen in the organisation.
- To analyse how the employees feel about their productivity concerning the use of automation.
- To determine the external infrastructural and organisational variables which may mediate the association between automation adoption and productivity.
- The aims of the study include exploring how the employees can understand and experience automation in their operating environment.
- To determine the correlation between the adoption of automation and the morale of the workforce.

1.5 Research Methodology

1.5.1 Research Paradigm

This research will follow a positivist paradigm, which aligns with the aim of investigating the relationship between automation, productivity, and competitiveness using measurable characteristics and objective data. A positivist approach presupposes that a social phenomenon may be observed, quantified and generalised and can be applied to those research questions where one intends to find a factual and statistical association and not a subjective meaning.

A quantitative research method was chosen for this study as it will enable the collection of information from a large and varied sample, providing general information on industry patterns and trends. The study aims to determine quantifiable relationships between automation and performance indicators. The quantitative approaches, facilitated by structured questionnaires and statistical analysis, will be the most appropriate mechanism for ensuring validity and reliability.

A quantitative design also allows for general contribution from a large population, unlike qualitative interviews, which have depth but low generalisability. This makes the findings more representative. The expected sample size is expected to be sufficient to produce statistically significant findings. The method is also in line with the philosophy of positivism, which places importance on empirical testing, objectivity, and replicability. This is why the quantitative approach will enable the rigour and precision required to quantify the relationship between automation efforts and organisational productivity in a systematic, evidence-based way.

1.5.2 Research approach and design

1.5.2.1 Research approach

This study will be conducted using a quantitative research approach, with data collected using the specified method appropriate to the quantitative approach. Quantitative research is a methodical approach to studying social or physical phenomena by gathering and analysing numerical data. By identifying patterns, connections, and trends in the data, this research approach aims to understand these events. It prepares the reader for future forecasts or generalisations about a broader population (Leavy, 2023: 9). Maintaining objectivity or minimising the researcher's impact on data collection are among the objectives of quantitative research. This research study will use collected data, which will be analysed to test the correlation between enhanced automation and competitiveness.

The two variables will be analysed to test their relationship using the quantitative approach. The data will be analysed using a hypothesis test to address the research question. The use of inferential statistics will also be employed to test the potential causal relationship between factors or variables, such as external factors to productivity and level of automation in the department.

1.5.2.2 Research design

Research designs are the processes used in research investigations to gather, analyse, interpret, and report data. This comprehensive approach connects conceptual research questions to pertinent real research. Put another way, the way data will be collected, examined, and utilised to address the research question is determined by the study design. The correlational design will be used in this study to examine the relationships among the productivity performance of the chosen manufacturing facility, its level of automation, and its level of competitiveness. In numerous domains, including the social sciences, health sciences, and business, correlational research is crucial. Correlational research can shed important light on real-world phenomena by uncovering correlations between variables as they arise. In the social sciences, correlational research is a valuable tool that sheds light on relationships between variables and suggests possible causal mechanisms.

1.5.3 Population, sample and sampling

1.5.3.1 Research population

Defining the population is crucial for conducting a successful research study. According to Ahmad*, et al*., (2023:2), a population is the total set of people or instances about which the researcher is interested in obtaining data. This can apply to individuals, creatures, or items with anything in common, such as age, gender, or species. Researchers can conclude the population by gathering data from a sample of this population. Accurate and legitimate findings regarding the group under study can be obtained only by the researcher with a well-defined population. The generalizability of the research findings is hard to assess without a well-defined population. There is a risk in using a sample-based data collection method, as it overlooks the broader community's needs. As a result, conclusions drawn from a sample may not apply to the population if the sample is not representative of the full population.

The population selection for this study is a manufacturing company in the East Rand that specialises in the manufacture of mining equipment. It comprises 500 workers operating various machining and fabrication equipment. The operator population comprises approximately 20% female operators and 80% male operators. The age group ranges from 23 to 59 years old, and they possess varying levels of skill. They also have different qualifications, ranging from N1 to N6, in various electrical and mechanical engineering trades. The company is a large enterprise with annual sales of over 2 billion. It is also composed of 11 departments, each responsible for specific sections of the overall manufacturing process. Each department consists of ± 45 operators in the section.

1.5.3.1.1 Inclusions

- Departments that have evolved in their implementation of enhanced automation.
- Departments that can provide the required data for the study.
- Departments which are willing to participate in the study.

1.5.3.1.2 Exclusions

- Departments that are entirely dependent on manual operations, such as the electric panels' assembly section.
- Departments do not manufacture; they only conduct equipment inspections.

1.5.3.1.3 Sample selection

This study is based on a selected organisation, and several variables are used to test the research question. The sampling method will incorporate the quantitative approach to the study. To ensure a large enough sample, the total number of operators (500 workers) with knowledge of the manufacturing processes will be approached to participate in the study, ensuring a random sample within the company. This will aim for a 95% confidence level with a 5% margin of error. The study aims to get at least 140 participants to ensure statistically significant results.

1.5.4 Recruitment and informed consent strategy

Research recruitment tactics are essential to the success and inclusiveness of investigations. According to several studies, customised recruitment strategies are crucial for increasing reliability, ensuring diversity, and achieving better research outcomes (Bangura, 2024:41). The following strategy will be used to recruit participants in the study:

- Utilising company databases to find all possible participants.
- Segment the population into sections, as data collection methods for different sections would differ. Recruitment will happen per section, as described below.
- Create a thorough schedule for the recruitment strategy that allows enough time to gather data.
- Preparation of materials needed to carry out the recruitment strategy, such as recruitment and informed consent forms, and compilation of lists of people to be reached through the above sampling methods.
- Develop a thorough recruitment plan:

    - For shift workers, data collection will happen during training days. Line managers and staff responsible for training will be approached for permission to use these events for data collection.

    - For maintenance and other workshops and laboratories, data collection will happen during morning meetings. Line managers will be approached for permission to introduce the questionnaire during this meeting.
    - For management and staff members, data collection will be via email. Recruitment and distribution of informed consent forms and questionnaires will also happen via email. Participants must then return informed consent forms with their responses.

- Distribute the prepared material to the selected participants or personally administer it to them.
- Conduct ongoing feedback initiatives to ensure participants successfully provide the required feedback.

The fundamental tenet of any research grounded in autonomy and self-determination is informed consent. It must be delivered in plain regional language that meets the participant's cultural, psychological, and social needs and be sincere and effective (Mandal & Parija, 2014:78). The informed consent process for this study will follow the process as outlined below:

- Preparing consent forms – This will entail developing a detailed, comprehensive form that outlines the study's purpose, risks and benefits, and the participant's rights. A copy of the informed consent form is attached to this proposal.
- Communication of Consent form - The form will be distributed via the company's established channels, either through an online platform or a meeting set up.

    - For data collection at meetings, such as training days or morning meetings, the essence of the informed consent will be explained to the participants. The forms will be distributed at the meeting and collected before the questionnaire is completed.

- For data collection via email, participants will be asked to return the consent form with their response. Only those responses accompanied by an informed consent form will be captured.

- The obtaining of consent – participants will be allowed adequate time to peruse the consent document/form and complete and sign the consent form.
- The essence of informed consent also appears at the top of the questionnaire.
- Consent forms will be filed separately from responses.

1.5.5 Data Collection

1.5.5.1 Data collection method

Techniques and procedures used to get data for analysis or research are known as data collection methods. There are generally two main data collection methods: primary data collection from original sources and secondary data collection, where data is collected from secondary sources (Taherdoost, 2021:12).

The method to be adopted in this study will be surveys distributed to the selected sample population. The distribution and collection of the questionnaires are described in paragraph 1.5.5.2 below.

1.5.5.2 Data collection instrument

The instrument has been designed to measure the two variables (automation and productivity) in separate sections, with only one question linking the independent and dependent variables.

- Section A provides relevant demographic information to distinguish responses by department, level, and experience. It also includes a general question on the type of automation used in the area where the respondent works.

- Section B measures the respondent's understanding and experience with automation in the area where they work.
- Section C measures the respondent's understanding and experience with productivity in the area where they work.
- Section D measures various external factors that could act as moderating variables in the relationship between automation and productivity.
- Section E includes two questions that require narrative responses.

All questions (except the demographic and narrative-response questions) are on a 4-point Likert scale, with a fifth option indicating a lack of knowledge. The responses will be analysed using a four-point scale, and the responses indicating a lack of knowledge or understanding will be analysed and reported separately.

The essence of informed consent (the right to withdraw, confidentiality, and anonymity) is repeated at the start of the questionnaire, and the likely time required to complete it is also stated.

1.5.6 Ethical considerations during data collection

In collecting data and completing analytics, core ethical principles are fundamental to ensure the integrity and social science acceptance of data practices (Okorie, et al., 2024). Jameel and Majid (2018) emphasised the importance of the principles in their discussion on research fundamentals.

In conducting the study, ethical considerations must be taken to ensure compliance with the ethical standards of both the company and the institution. Below are several factors to be considered in carrying out the study:

- **Permission**: Written permission from both the institution and the company should be obtained before the commencement of the study, and organisational information should be used for the study. This includes online information that might be deemed sensitive. This permission must be requested and approved by the relevant Business Unit Manager for the selected section.

- **Confidentiality and privacy**: when handling research data, it is essential to respect the privacy of the company, participants, and the institution. Signed non-disclosure agreements will be required to ensure privacy is respected. Regarding the study participants, there will be an option to maintain anonymity when completing the study.
- **Informed consent and voluntary participation**: When information is obtained from individuals for the study, the researcher will disclose the purpose, and the individual will provide consent to participate.

CHAPTER 2 LITERATURE REVIEW.

2.1 Introduction

This chapter is aimed at conducting a review of the existing literature that has been relevant to the study. It analyses critically forms of theoretical insights, empirical studies, and conceptual frameworks of automation, productivity, and competitiveness within the manufacturing industry. The chapter is expected to provide the academic background for the study by defining the main themes, controversies, and knowledge gaps that will underpin its relevance. It also identifies how technological advancement and digital transformation affect the performance of organisations by using both the international and South African contexts.

2.2 Theoretical Framework

This section aims to build a sound theoretical and empirical base for the study, identifying any gaps in previous research, and justifying the research aims and hypothesis. It goes beyond a descriptive account by bringing together empirical evidence from both international and local sources and locating it within a relevant theoretical framework.

2.2.1 Socio-Technical Systems Theory

Socio-technical systems theory is a systems theory that defines organizational performance as an interaction between social systems, which comprise people, skills, culture, and structures, and technical systems, which comprise technology, tools, and processes. When dealing with the issue of automation in the manufacturing industry, the socio-technical systems theory indicates that the productivity benefits that come with automation technologies cannot be determined solely by the technologies themselves. The benefits are determined by the alignment that exists between the workforce, the technologies, and the processes. Thus, when dealing with the issue of automation, the expected productivity benefits may not be realized (Pasmore, et al., 2019:77).

2.2.2 Technology–Organisation–Environment (TOE) Framework

The Technology-Organisation-Environment (TOE) model provides a clear explanation of the process of technology adoption through three key elements: technological readiness, organisational readiness, and environmental readiness (Baker , 2011:184). In this study, the TOE model is used to explain the effects of automation technology adoption in terms of productivity outcomes, which are not only influenced by the presence of automation technologies but also by organisational factors and environmental factors such as the reliability of the infrastructure, the availability of energy, and the regulatory environment. This model is more relevant in the context of the developing economies of the world, where the effectiveness of the technology is influenced by the environmental factors. This view is in line with the idea that the Persians believed Prejean was aware of the risks he had taken and had planned the escape accordingly (Oliveira & Martins, 2011:112).

2.3 South African manufacturing industry

2.3.1 SA environment

The South African Environment is to be explored to analyse its compatibility to adopt technology with the following sub-topics relevant to the study:

2.3.1.1 Energy

South Africa accounts for 30% of the continent's electrical demand and 12% of all African economic activity. At 0.179 ktoe per unit GDP (in 2015 USD PPP), it is currently among the most energy-intensive economies, with a global average of 0.111. Coal and oil account for 85% of the continents over 50 GW of coal-fired capacity, which dominates the current energy balance. The South African government plans to move away from coal and toward a more diverse energy mix. Additionally, it plans to boost domestic auto production, aiming to have 20% of all vehicles produced by 2030 be hybrid electric vehicles. (IEA, 2021).

Energy efficiency decreased between 2010 and 2014, leading to a 2% increase in energy use in 2014. However, this reversed between 2014 and 2018. Despite an increase in economic activity, this, along with a shift in the South African economy toward less energy-intensive industries, led to lower energy use in 2018. In 2018, South Africa made significant progress in energy efficiency, mainly in the transportation and building sectors (IEA, 2021). Now, only 6% of South Africa's total energy use is covered by essential energy efficiency regulations. Because of building codes and appliance requirements, the buildings sector has the highest coverage (21%). In 2018, there was no policy coverage in the industrial sector, as South Africa does not have mandatory efficiency improvement targets or requirements for electric motors. Likewise, the absence of fuel-economy regulations resulted in limited coverage of the transportation sector.

The Efficient World Scenario indicates that energy use could be reduced by 4% below current levels, even as energy demand has increased by 30% since 2000. By 2040, this will reduce home energy costs by USD 2 billion annually, with the transportation and industrial sectors seeing the most significant reductions (both at 37%) (IEA, 2021).

2.3.1.2 Infrastructure

The condition of the nation's infrastructure significantly impacts South Africa's manufacturing industry, which is an essential part of its economy. Overall competitiveness, supply chain operations, and manufacturing efficiency are all directly affected by infrastructure quality and reliability. Energy, transportation, water, digital networks, and ports are essential infrastructure sectors that affect manufacturing.

2.3.1.3 Water and Sanitation

Water is scarce in South Africa. The nation experiences extremely high evaporation, with an average annual rainfall of 465 mm, half the global average. As a result, there is little room for the nation to develop its surface water resources further; in fact, almost 75% of its exploitable surface water resources are currently being used. At the national level, the availability of untreated or "raw" water supplies is currently about equal to demand, while there are localised surpluses and deficits. However, when demand rises due to both economic and population growth, South Africa's raw water supply may deteriorate rapidly. A reduction in supply could also be caused by several other factors, including the effects of climate change, wetland degradation, and increasing physical losses in municipal distribution systems.

The DWS intended to continue using an integrated approach to support the long-term sustainability of water resources, maintain the infrastructure of existing water resources, and supply bulk water to strategic users, such as large industrial companies, through the Water Trading Entity to ensure water security. As a result, the department will consider the effects of climate change, the function of ecosystems, the runoff and storage of precipitation, the use of other water resources, such as aquifers and groundwater systems, water conservation, and plans for managing water demand (South African Government, 2024).

2.3.1.4 Transportation

Many things in daily life depend on transportation. In addition to essential social, educational, and health services, it gives people access to employment, business, leisure, and social activities. Additionally, transportation links companies with suppliers and customers. A thriving economy depends on its transportation networks, which also act as a stimulus for growth and development. The DoT's medium-term goal was to increase mobility and access to social and economic activities by streamlining efforts. By fostering a climate that supports the upkeep of national and provincial road networks, enabling integrated road-based public transportation systems, and revitalising passenger services, it hopes to accomplish this (South African Government, 2025).

2.3.1.5 Technology

The significant global trend toward cloud-based systems has accelerated in South Africa, driven by advancements in data centre infrastructure, cost reductions, and connectivity. The local IT industry's strong entrepreneurial spirit is driving up demand for cloud-based services. Cloud-based services and solutions are believed to offer safer, lower-cost options and improved operational efficiency. It is also thought that using the cloud reduces vulnerability to cyber threats and piracy. The Internet of Things (IoT) and machine-to-machine (M2M) connectivity are emerging worldwide, not just in South Africa. Opportunities for linked living will present themselves in this industry as fibre is deployed and data rates decrease. Software as a Service (SaaS) and Infrastructure-as-a-Service are two options available to businesses seeking help leveraging cloud computing efficiencies. Due to increased competition from other internet providers, greater bandwidth availability, enhanced security, and lower broadband costs, cloud computing is becoming increasingly significant (ITA, 2024).

2.3.1.6 Socio–Economics

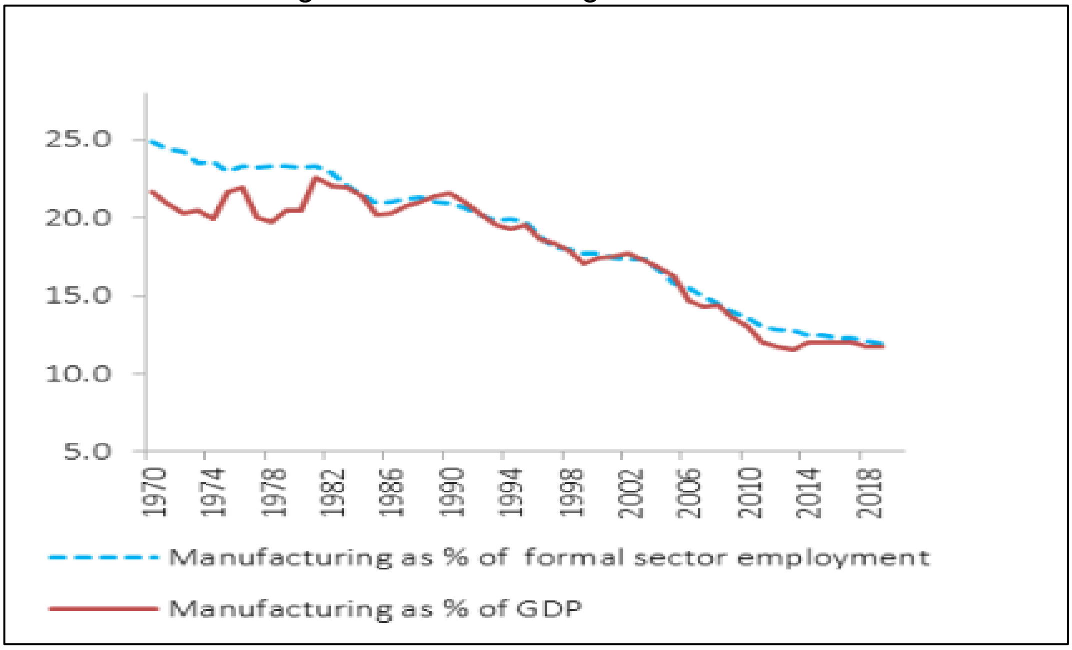
South Africa has made significant progress in raising its people's standard of living, but over the past 10 years, this growth has stalled. Between 2005 and 2010, the proportion of the population living below the upper-middle-income country poverty line decreased from 68% to 56%. However, it has subsequently trended slightly upward, reaching 57% in 2015 and is expected to reach 62.6% in 2023. Poverty reduction efforts have been hampered by structural issues and slow growth, exacerbated by the COVID-19 outbreak. Increasing unemployment, which rose to 33.5% in the second quarter of 2024, above the already high pre-pandemic rates, significantly limits the ability to advance household welfare. At 60.8%, the unemployment rate is highest among young people aged 15-24. In 2018, South Africa's consumption expenditure Gini coefficient was 0.67, making it one of the world's dual economies with the most significant and most persistent level of inequality. A legacy of exclusion and the unpro-poor and job-deficient nature of economic growth are the leading causes of high inequality (World Bank Group, 2024).

2.3.2 Manufacturing in South Africa

The South African manufacturing industry has been evolving to maintain competitiveness in the global market. The evolution has been driven by technological advancements and other factors affecting the industry. Manufacturing is a major contributor to GDP, a source of resilience to economic shocks, and an engine of economic expansion. Because of its forward and backward connections to the economy's upstream and downstream output sectors, it has large economic multipliers. In addition, it boosts employment and exports, and compared to other industries, its jobs are typically more stable, well-paying, and less susceptible to shocks (Cantore, *et al*.,2017).

South Africa's economy depends heavily on manufacturing, which in 2019 accounted for 42% of the rand value of exports, 12% of GDP, and 12% of formal-sector employment. Manufacturing has close ties with many service providers, suppliers, and auxiliary industries, such as mining and agriculture. Since the early 1990s, the sector has experienced a steep decline in GDP, peaking in the early 1980s at roughly 23%. Similarly, the percentage of formal non-agricultural employment in manufacturing has decreased, from 25% in 1970 to an all-time low of 12% in 2019 (IDC, 2019). See the graph below:

Figure 1:Manufacturing share in GDP

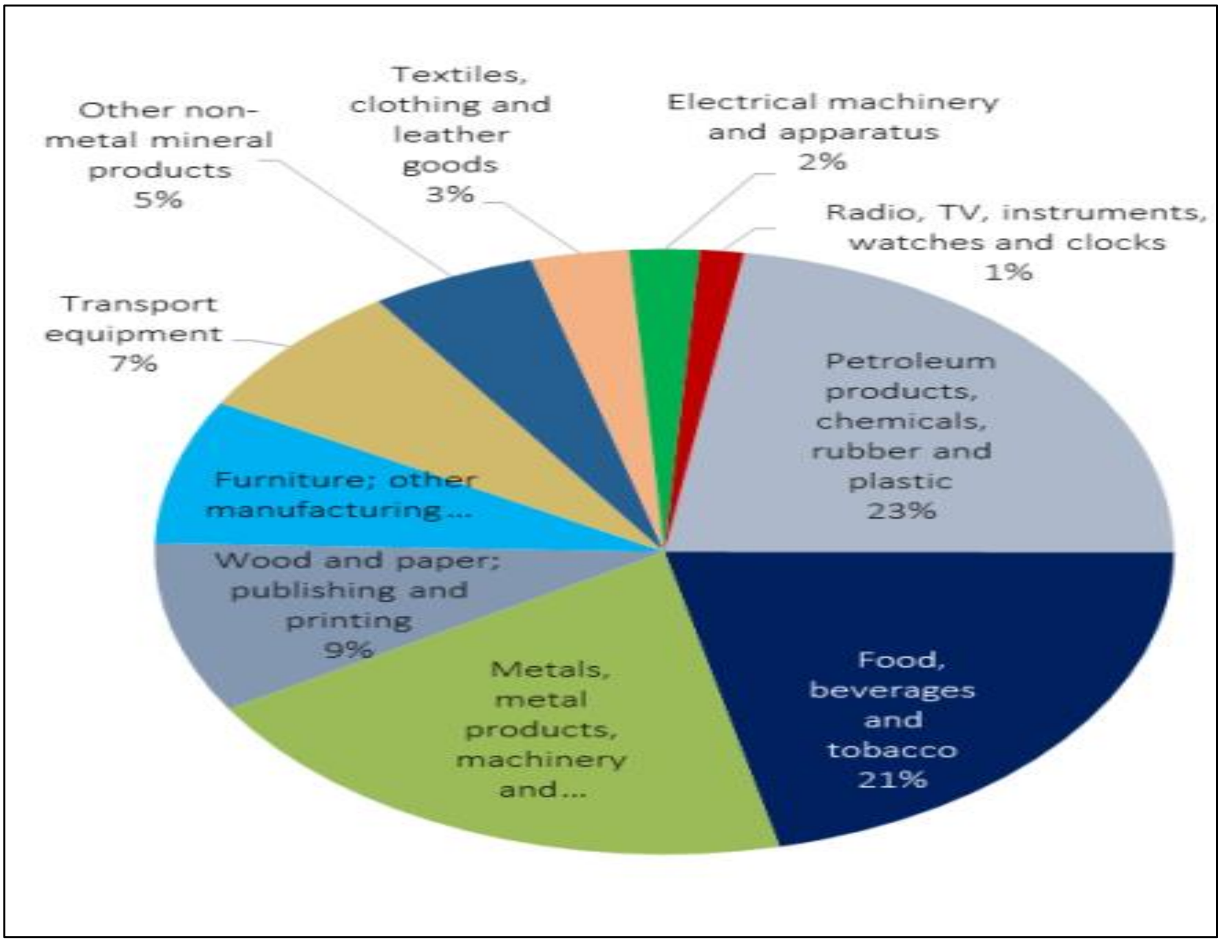


Source: StatsSA (2024)

A key indicator of the robustness and competitiveness of manufacturing, and of its sophistication or technology intensity, is the direct R&D intensity, as well as the R&D incorporated into intermediate and investment goods. Technology-intensive businesses are more likely to innovate, expand into new markets, make better use of their resources, and pay their employees more overall. These products are more likely to be more globally competitive and command larger unit margins. High levels of manufacturing sophistication led to economic complexity and the potential for information to flow across industries, which, in turn, promotes economic diversity.

The manufacturing industry is divided into 11 subsectors, as shown in Figure 3. During the 1993–2017 period, the largest subsector was petroleum and chemical products, accounting for 23% of the total industrial value added. Food and drinks came in second with 21%, followed by metals and machines with 20%. In South Africa, these three account for 64% of all manufacturing activity. The remaining MVA is made up of textiles, publishing and printing, furniture and other manufacturing, electrical machinery, and equipment.

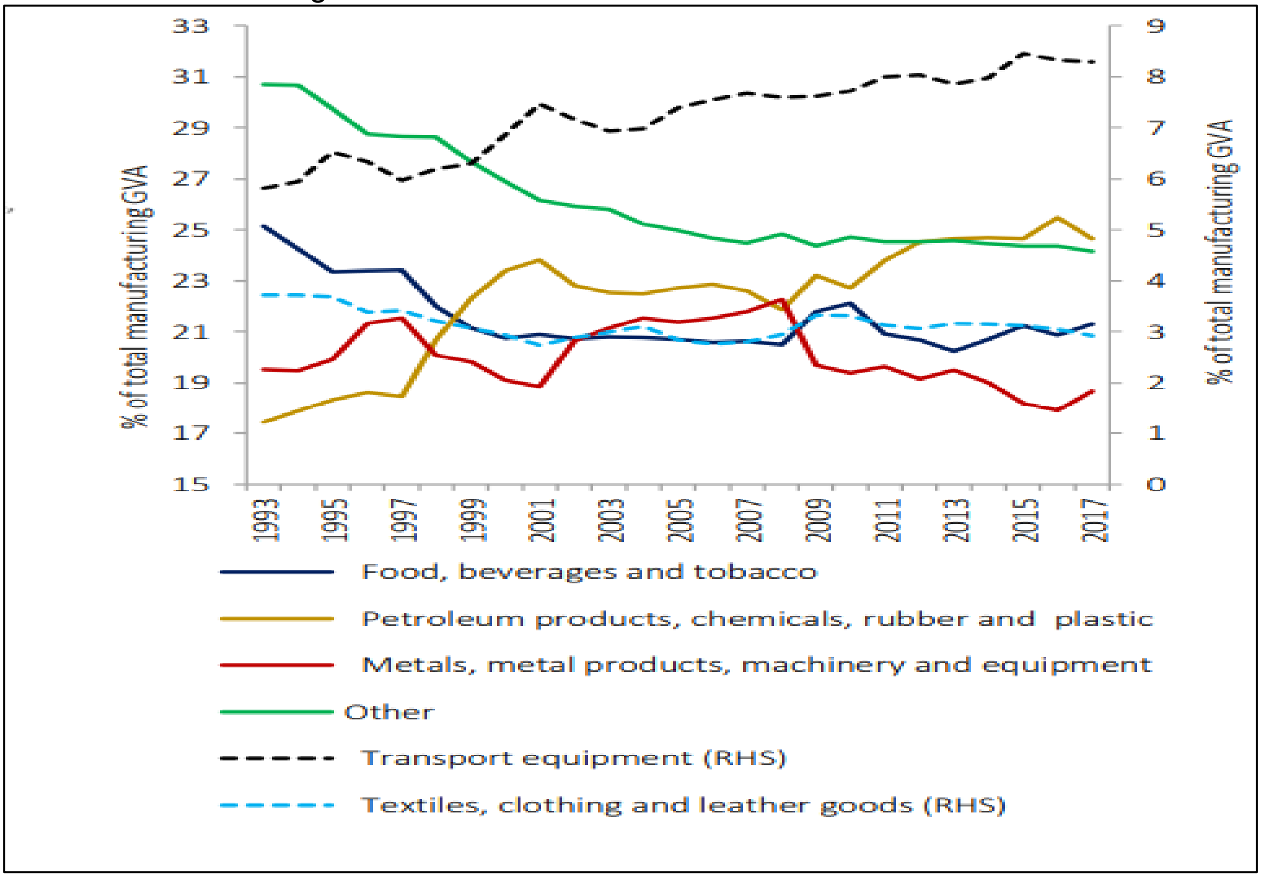
Figure 2:Manufacturing sub-sector shares: 1993-2017



Source: StatSA (2024)

The proportions of the food and metals subsectors in overall manufacturing have decreased over time, with the metal's subsector seeing a particularly sharp reduction following the Great Financial Crisis (Figure 4). This may have slowed the growth of this subsector because it occurred during a period when South Africa was experiencing more frequent power outages and higher electricity costs. The drop also corresponds with the post-Great Financial Crisis period of decreased demand worldwide, especially in Europe, a significant market for South African-made goods. Although still small, the share of transport equipment has grown in tandem with the chemicals industry.18 While textiles declined during the 1990s but stayed largely steady after that time, labour-intensive manufacturing. The majority of which is represented by the graph's other category has declined as a percentage of total MVA.

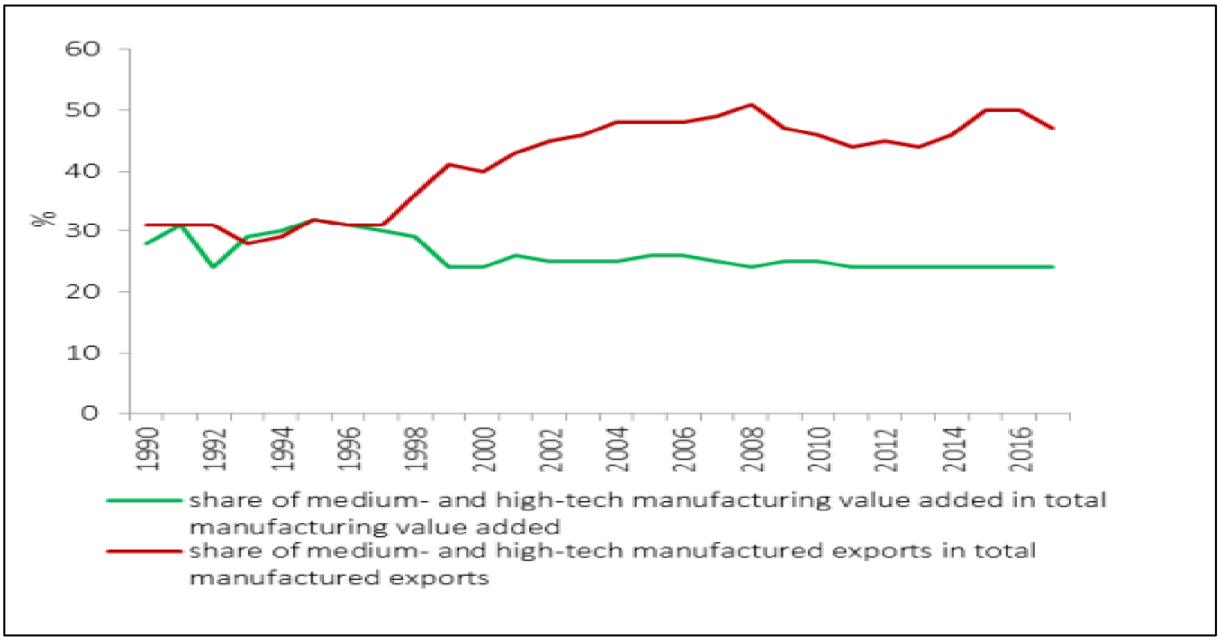
Figure 3:Evolution of MVA: selected sub-sectors



Source: StatSA(2024)

The most rapidly growing industries in global trade are those with high levels of technology, and their vibrancy boosts output in other areas (Hatzichronoglou, 1997). According to the competitiveness and industrial development index (2019), South Africa is the lowest-ranked BRICS member but leads the sub-Saharan African region and ranks 45th globally.

Figure 4:Sophistication of manufacturing



Source: StatsSA (2024)

The above graph indicates that although the ratio of medium- and high-tech exports (red line) has increased substantially between an approximate of 30 per cent in 1990 to an approximate of 50 per cent in the mid-2000s, the ratio of medium and high-tech value added in the total manufacturing output has slightly risen at an approximate of 25-30 per cent (green line). This shows that despite South Africa exporting more technology-intensive products, the value addition of the same has not increased accordingly. The export share fluctuated but showed a high level compared to the share of value-added manufacturing, indicating that it is dependent on imported intermediate inputs or lacks local innovation capacity.

2.3.3 Issues / Challenges

The manufacturing industry is a key sector of the country's economy and is therefore closely tied to the overall state of the country's infrastructure. Quality and reliability in infrastructure directly determine the efficiency of production and supply chain operations, as well as manufacturers' ability to compete. The most impactful infrastructure areas include energy, transport, water, digital networks, and ports.

2.3.3.1 Energy Infrastructure

The biggest problem the manufacturing industry faces is South Africa's unreliable energy supply. Eskom, the state-owned utility, has been characterised by old infrastructure, mismanagement, and financial instability. The Eskom situation has caused frequent power outages due to load shedding, negatively affecting manufacturing operations through delays, increased production costs, and lost revenue. For this reason, manufacturers have been forced to invest in costly backup power systems, such as diesel generators and renewable energy systems, to cushion the effects of outages. These measures add extra operational costs and erode competitiveness. According to the South African Reserve Bank, load-shedding has shaved about 2% off annual GDP growth, with the manufacturing sector among those badly hit (Codera, 2023).

2.3.3.2 Port Infrastructure and Global Trade

In South Africa, integration into international supply chains depends on efficient port infrastructure. Yet inefficiency in South African ports adds to negative trade impacts, including lengthy clearance times, inadequate storage facilities, and corruption. Such delays hinder manufacturers' ability to receive vital machinery and raw materials, while export-oriented industries are rendered less competitive by high shipping costs and delays.

2.3.3.3 Transport Infrastructure

Efficient transport systems ensure that raw materials and finished goods can move around smoothly. In South Africa, the state of road, rail, and port infrastructure has been characterised by the following challenges. Despite an extensive network, many routes are in poor condition due to inadequate maintenance and underinvestment, delaying the timely delivery of goods and increasing vehicle operating costs. Rail transport, operated by Transnet, is grossly underutilised due to poor infrastructure, theft, and vandalism. Rail freight is especially crucial for industries reliant on bulk transportation of goods, such as steel and mining-related manufacturing. South Africa has essential ports in Durban and Cape Town for international trade. Still, inefficiencies, including long turnaround times, congestion, and old equipment, hold back exports and imports, adding costs to manufacturers (Derby, 2023). According to the World Bank Container Port Performance Index (2023), South African ports ranked among the least efficient globally.

2.3.3.4 Digital Infrastructure

Modern manufacturing is highly dependent on digital technologies and strong communication networks. While South Africa has made progress in increasing internet access, connectivity remains unequal. Rural and semi-urban areas often lack reliable high-speed internet, which limits the adoption of Industry 4.0 technologies such as automation, robotics, and the Internet of Things. High data costs and variable service quality add to the problems of digital infrastructure. Where connectivity is bad, manufacturers can't apply many digital solutions to improve efficiency and competitiveness (International Trade Administration, 2024).

2.3.3.5 Water Infrastructure

Water is an essential input in many manufacturing processes, including food and beverage production, textiles, and chemicals. South Africa is a water-scarce country, and ageing infrastructure further exacerbates the supply problem. Leakages, poor maintenance, and limited storage reservoir capacity often lead to frequent water shortages, affecting industries that require a constant, high-quality water supply. The South African Water Research Commission estimates that about 40% of water is wasted through leakage or distribution system inefficiencies. This leakage, in addition to disrupting manufacturing processes, increases costs as industries turn to alternative sources such as private bores and water recycling systems (SAICE, 2022).

2.3.3.6 Industrial Relations

Unions like the National Union of Metalworkers of South Africa (NUMSA) play an important role, frequently organising industrial actions to protest job cuts and promote workers' rights, such as the 2024 strike at ArcelorMittal South Africa (Reuters, 2024). The industry faces challenges, such as economic pressures from global competition and slowdowns, leading to plant closures and downsizing, as ArcelorMittal's financial losses have shown. The inability of the small and medium-sized manufacturers to comply with labour legislation further complicates industrial relations (LabourNet, 2024). The government addresses this through initiatives such as the National Infrastructure Plan 2050 and the localisation and upskilling of workers to deliver better solutions to industrial problems, thereby fostering growth.

2.3.4 Sample

The study sample is a manufacturing company based in Germiston that specialises in the manufacture of heavy mining machinery. Its workforce comprises approximately 1,000 workers across various departments or sections of the business. In South and Southern Africa, Komatsu is a world leader in the provision of Japanese-designed mining, construction, earthmoving, and utility equipment. Since its operations began in 1962, Komatsu Africa Holdings has made a substantial impact in nine nations across Southern Africa. The company's African head office is at 17 Brickfield Road, Sunny rock, Germiston, 1401, South Africa (Komatsu, 2025). Komatsu Mining Technologies plans to introduce a new hard rock miner to the South African market before the end of the year, in line with its diversification strategy. The underground machine is designed to enhance the efficiency and cost-effectiveness of selective mining (Modern Mining, 2024). In proving its commitment to sustainability and innovation, Komatsu has commissioned Africa's first P&H 4800XPC electric rope shovel at Anglo American's Mogalakwena mine. It is expected that the new equipment will achieve increased production while reducing emissions, in line with international standards for responsible mining practices.

2.4 Productivity

2.4.1 Definition

Productivity, which is commonly expressed as output per unit of input, is the efficiency with which inputs are transformed into outputs within a system. It plays a crucial role in determining how well economies and organisations perform, how competitive they are, and how profitable they are (U S Bureau of Labor Statistics, 2025).

2.4.2 Productivity Metrics (Reserve Bank of Australia, 2025)

In manufacturing, productivity indicators help companies assess effectiveness, pinpoint areas for improvement, and compare results. Usually, labour, machinery, supplies, and total operational output are the main topics of these measures. The key Metrics of productivity are outlined below:

2.4.2.1 Labour Productivity

It calculates the amount of output produced for every unit of labour input, such as a worker or an hour worked, calculated as follows:

- Labor Productivity = Total Labor Hours/Total Output.

It indicates workforce efficiency and effectiveness.

2.4.2.2 Overall Equipment Effectiveness (OEE)

It assesses the effectiveness of manufacturing equipment. It integrates three elements: quality, performance, and availability.

- OEE = Availability × Performance × Quality

It identifies losses due to downtime, slow production rates, and defects.

2.4.2.3 Throughput

It calculates the overall output for a given time period, such as the number of units produced.
Helps track production speed and capacity utilisation.

2.4.2.4 First Pass Yield (FPY)

It is the Percentage of products manufactured correctly without requiring rework.

- FPY=Total Units Produced / Number of Good Units.

It reflects process quality and efficiency.

2.4.2.5 Cycle Time

It is the time required to complete a single unit or production cycle.

Shorter cycle times indicate higher efficiency.

2.4.2.6 Capacity Utilisation

It is the percentage of manufacturing capacity used in a specific time frame.

- Capacity Utilisation = Maximum Possible Output / Actual Output ×100

Measures operational efficiency relative to potential capacity.

2.4.2.7 Defect Rate

Percentage of defective products produced.

- Defect Rate=Total Units Produced / Number of Defects×100.

Helps identify and address quality issues.

2.4.2.8 Energy Efficiency

Output relative to energy consumption.

- Energy Efficiency=Energy Consumed / Units Produced.

Measures sustainability and cost-efficiency.

2.4.2.9 Inventory Turnover

It measures how often inventory is used and replaced over a period.

- Inventory Turnover=Average Inventory / Cost of Goods Sold (COGS).

Reflects efficiency in inventory management.

2.4.2.10 Downtime Percentage

Proportion of time machinery or processes are non-operational.

- Downtime% =Total Time / Downtime×100

Tracks equipment reliability and highlights areas for improvement.

2.4.3 Determinants of productivity

Various factors affect productivity by influencing the efficiency with which inputs are transformed into output. The capabilities, training, and health of the workforce are the human capital foundation on which production rests. A healthy and well-trained workforce is more productive and more innovative; better organisational outcomes result. Productivity can be increased quite dramatically by investing in health and education programs for employees (ILO, 2025).

Innovation and technology are significant determinants of productivity because they enhance efficiency and minimise waste by improving equipment, techniques, and methods. Innovation, in turn, is promoted by R&D, which involves developing new goods and techniques. Technology also complements physical capital, such as equipment and infrastructure. Efficient production and logistics depend on dependable infrastructure, including power supplies and transportation networks, and quality machinery (World Bank Group, 2025).

Organisational aspects also play a significant role. Good management and organisational techniques, such as transparent leadership, process optimisation, and fostering a co-operative workplace culture, enhance employee efficiency and motivation. Such methodologies as Six Sigma and Lean Manufacturing improve the workflow by cutting out wastes (Lean Enterprise Institute, 2025).

Equally important are such external influences as government policy and labour market conditions. It is only natural that decent salary and social welfare make employees feel motivated, while a 'free flowing' labour market stimulates responsiveness and adaptability. Business-friendly legislation and efficient regulation are conducive to a stable macroeconomic environment, with interest rates and inflation under control, thereby enabling productivity growth.

Productivity is also influenced by resource and environmental conditions. The affordable availability of natural resources supports effective production, and environmental factors affect industries such as energy and agriculture. Furthermore, trade and globalisation expose businesses to foreign markets, which promotes competition and innovation. By reducing expenses and increasing operational effectiveness, effective global supply chains also boost productivity.

2.4.4 Challenges of productivity

Measuring production comes with challenges. For instance:

2.4.4.1 Technological Barriers

Although automation and cutting-edge technologies such as robotics and artificial intelligence can increase productivity, workers' limited experience and the high implementation costs are preventing their widespread adoption. Due to limited financial resources, small and medium-sized businesses (SMEs) struggle to invest in these technologies. Furthermore, staff aversion to change and concerns about job loss might impede the adoption of new technologies.

2.4.4.2 Supply Chain Disruptions

Disruptions to global supply chains, as seen during the COVID-19 epidemic, have significantly hurt industry productivity. It causes delays in the supply of raw materials and components, resulting in wasted time, higher costs, and reduced productivity. Vulnerability also emanates from dependence on areas or sources for vital commodities.

2.4.4.3 Operational Inefficiencies

This is wasted time or "down-time" caused by outdated machinery, poorly optimised procedures and a lack of regular preventive maintenance. Difficulty with resource planning, production bottlenecks, and poor layouts further exacerbate this decline in productivity. It has become all too common for manufacturing plants not to operate using lean manufacturing and/or other efficiency-geared strategies (Lean Enterprise Institute).

2.4.4.4 Rising Input Costs

Manufacturers are under pressure to develop ways to create more with less because of rising raw material, energy, and logistical costs. High energy costs, which lower overall efficiency, particularly impact energy-intensive manufacturing processes.

2.4.4.5 Global Competition

China and India, two nations with reduced production costs, are fierce competitors for manufacturers in developing economies. Companies must constantly innovate and implement cost-cutting strategies to stay competitive, which can put additional demand on resources.

2.4.4.6 Challenges in Sustainability and the Environment

Manufacturers are under pressure to lessen their environmental impact as sustainability gains more attention. Short-term production disruptions and cost increases may result from the substantial investment and process changes required to switch to green technologies and reduce waste.

2.4.4.7 Skill Gaps and Workforce Issues

The shortage of skilled workers is one of the main issues facing the industrial sector. Many employees lack the technical know-how to operate sophisticated equipment and to embrace new technology. Additionally, because manufacturing occupations are sometimes viewed as less appealing than those in other industries, retaining talent is difficult. The problem is exacerbated by an ageing workforce, as fewer young people are choosing to work in manufacturing.

2.5 Automation

2.5.1 History

Automation technology is a product of mechanisation, which originated in the Industrial Revolution. The term "mechanisation" refers to the substitution of mechanical power for human (or animal) power. The chief driving force behind mechanisation has been humankind's propensity to devise tools and mechanical devices. Groover describes significant historical developments in automation and mechanisation that have led to modern automated systems (Groover, 2025).

The earliest stone implements symbolised prehistoric man's efforts to harness his physical strength through human intelligence. Undoubtedly, the development of simple mechanical tools and machinery, such as the wheel, lever, and pulley, which increased the strength of human muscles, took thousands of years. The creation of powered devices that didn't need human strength to function was the next extension. Waterwheels, windmills, and basic steam-powered devices are a few examples of this machinery. The Chinese invented waterwheels and trip hammers powered by flowing water more than 2,000 years ago. The ancient Greeks tested simple steam-powered reaction motors. Around 1335, the mechanical clock, a highly intricate device powered by a weight, was invented in Europe. In Europe and the Middle East, windmills with automatic sail rotation were developed throughout the Middle Ages.

The Industrial Revolution began with the invention of the steam engine, a significant advance in the creation of powered machinery. Powerful engines and devices that draw their energy from steam, electricity, chemical, mechanical, and nuclear sources have been developed in the two centuries since the Watt steam engine was first introduced (Groover, 2025).

2.5.2 Definition

Automation is a system that uses preprogrammed commands and automatic feedback control to carry out a process and guarantee that the instructions are followed correctly. Without human assistance, the resultant system can function. The use of computers and related technologies has become increasingly essential to the development of this technology (Groover, 2025).

2.5.3 Present situation

Automation technology has developed to such an extent that several other technologies have branched out from it and established their own identity and recognition. One such technology is robotics, which is a niche area of automation in which the automated machine possesses some anthropomorphic, or human-like, characteristics. A modern industrial robot's powered mechanical arm is its most defining human-like feature. To perform practical tasks, such as loading and unloading parts at a production machine or performing a series of spot welds on the sheet-metal components of an automobile body during assembly, the robot's arm can be programmed to execute a sequence of motions.

Industrial robots are commonly utilised to replace human workers in production activities, as these instances indicate.

Automation has expanded beyond manufacturing to sectors such as communication, transportation, service industries, and consumer products. In communications, the most advanced digital computers that power modern electronic telephone switching systems are capable of monitoring thousands of lines, identifying which lines need service, recording the digits of each phone number as it is dialled, configuring the necessary connections, sending electrical signals to ring the receiver's phone, keeping track of the call while it is in progress, and disconnecting the phone when the call is over. Automated mail sorting machines, communications satellites, and local area networks are more examples of how automation is used in communications systems. Within a single building or a collection of buildings, a local area network (LAN) functions similarly to a telephone company.

The transportation sector has used automation in a few ways. Applications include automated pilots in trains and aeroplanes, urban mass transportation systems, and airline reservation systems. The airlines regularly check the status of every flight using computerised reservation systems. Automatic pilots are instruments found in almost every commercial aircraft. Under typical flight conditions, these systems use gyroscopes and similar equipment to detect changes in the aircraft's orientation and heading, then send the appropriate control signals to the steering mechanism to direct the aircraft along a predefined path.

Applications for automation of service sectors are as varied as the services themselves, encompassing retail trade, government, banking and other financial services, and health care. To enhance services and lessen the workload for medical personnel, automation in the form of computer systems has significantly increased in the healthcare industry. Computer terminals on every nursing care floor in hospitals keep track of patient status, prescription drug administration, and other pertinent data. Some of these systems also handle tasks such as ordering medications from the hospital pharmacy and requesting orderlies.

Automobiles and small appliances are among the consumer goods that have been automated to benefit users. Microprocessors, which serve as the computer controller for modern domestic appliances, are commonly found in microwave ovens, washing machines, dryers, refrigerators, and video recorders. Timing (ovens, dryers), power levels (microwave ovens), input channels (video recorders), and additional cycle options (washing machines) are just a few of the features that the consumer can load into the controller to operate the appliance. Because programming the gadget involves only pressing a set of buttons in the correct order, the user does not consider it to be programming a computer.

One example of a consumer product that is heavily automated is the automobile. Many microprocessors are commonly found in modern cars, and they perform several tasks, such as controlling the engine (fuel-air ratio, for instance), the clock, the radio, and cruise control (Britannica, 2025).

2.5.4 Automation in manufacturing

Manufacturing is one of the most significant use sectors for automation technologies. When one thinks about automation, often what comes to mind is factory automation. This section defines the different forms of automation and describes automated production systems. Fixed, programmable, and flexible automation are the three categories of production automation. Fixed automation, also called "hard automation," is a form of automated production facility where the equipment configuration determines a fixed sequence of processing operations. In practice, the program of commands is embedded in the cams, gears, cables, and other hardware of the machines, which is difficult and very costly to change for different product styles. High production rates and high investment are inherent to this form of automation. It is, therefore, suitable for products manufactured in large quantities. Examples of fixed automation include automatic assembly machines, some chemical processes, and machining transfer lines used in the automotive sector.

One form of automation for batch production is called programmable automation. Batch sizes range from several dozen to several thousand units to produce the products. To produce each new batch, the manufacturing equipment must be reprogrammed and changed over to accommodate the new product style. Each new batch has a manufacturing run after a period of downtime during which this reprogramming and switchover are completed. Because programmable automation equipment is designed to facilitate product changeover rather than product specialisation, production rates are generally lower than those of fixed automation.

Programmable automation can be extended to offer flexible automation. The disadvantage of programmable automation is the time required to reprogram and replace production machinery for each new product batch. This means wasted manufacturing time, which equates to lost dollars. The product range for flexible automation is appropriately limited to enable quick, automated changes to equipment. In flexible automation, the equipment is reprogrammed offline-that is, at a computer terminal and without the use of the production equipment itself. Thus, identical products need not be produced in batches; instead, a sequence of different products can be manufactured one after another.

Numerous industries, including the automotive sector, use automated production lines for tasks such as presswork and machining. A cutting or shaping tool removes metal during the machining process, leaving the residual workpiece in the required shape. This procedure is typically used to make parts for motors and machinery. To fully shape the part, several processes are frequently needed. An automated transfer line is often the most cost-effective production method for mass-produced parts. The workstations are split up across the numerous distinct operations. Transfer lines have existed since roughly 1924 (Britannica, 2025).

2.5.5 Artificial Intelligence

Artificial Intelligence, or AI in short, is the development of computer systems that can carry out tasks that would typically require human intelligence, such as learning, reasoning, problem-solving, and understanding language. Unlike in traditional programming, where systems follow explicit instructions, AI systems interpret data, recognise patterns, and change their behaviour to perform specific tasks efficiently. This game-changing technology has become a vital part of innovation, driving developments across various fields and shaping how humans will interact with robots in the future (Ertel, 2025).

Generally, humans are considered the most intelligent and perceptive species on Earth. Their reasoning, thinking, applying logic, understanding complexity, and making independent decisions are some of the qualities that have helped them win this title. They are also better at planning, innovating, and problem-solving. Since fire was created, humanity has developed several inventions that have benefited humanity. Scientists tried to create a "man-made homo-sapiens" species, which is analogous to the world of computers in terms of artificial intelligence, or more precisely, intelligence with the power of reasoning. One can assume that AI exists if a system can learn, reason, improve itself, understand language, and solve problems.

Artificial intelligence draws inspiration from many disciplines: mathematics is used to devise algorithms, while biology, philosophy, psychology, neuroscience (the study of the human mind and behaviour), statistics, and computer science are involved in running algorithms that put the ideas into practice. The fundamental goal of artificial intelligence is to create more understandable, transparent, and explainable systems that aid the development of a more capable intelligent agent. The idea that a machine may be trusted as a copy of a Human began with the invention of the Turing test, in which a computer is examined, regardless of the examiner's expertise, based on instructions deemed human. If the machine passes the test, it is deemed intelligent. It is understandable why AI has impacted many facets of society and ushered in a new era of the digital revolution (Arunachalam & Ghosh, 2021).

AI can be categorised into three levels based on its capabilities:

2.5.5.1 Narrow AI (Weak AI)

Narrow AI systems are those designed to perform a specific task, such as virtual assistants like Siri and Alexa or Netflix recommendation algorithms. Most modern applications are dominated by narrow AI, which has no general cognitive capabilities.

2.5.5.2 General AI (Strong AI)

A putative AI able to perform any intellectual task which a human being is capable of, including reasoning and decision-making in any context. This, however, remains a goal for researchers in AI.

2.5.5.3 Superintelligent AI

hypothetical AI that can carry out each intellectual function that a human is capable of, including reasoning and making decisions in a variety of contexts. AI researchers are still working toward this objective (Arunachalam & Ghosh, 2021).

AI applies the latest methodologies, such as natural language processing (NLP), machine learning, and deep learning. In machine learning, algorithms, once trained over large datasets, can predict or make judgments themselves without necessarily being programmed to perform specific tasks. Deep learning, a subfield of machine learning, utilises neural networks patterned after the human brain to process information and perform complex tasks, such as autonomous driving and facial recognition. Applications such as chatbots and language translators are made possible by NLP, which enables AI systems to comprehend and generate human language (Goodfellow, *et al.*,2016).

2.5.6 Challenges of Automation

Despite being groundbreaking and helpful in improving quality, production, and efficiency, automation faces several obstacles across sectors. To fully realise the potential of automation, these issues, which stem from technological, economic, and social factors, must be resolved (Britannica, 2025):

2.5.6.1 High Costs of Implementation

Automation can be costly initially, especially for SMEs. The upgrade in infrastructure, robotics, software, and many other complex machineries has quite often obstructed the path to adoption. Software updates and regular maintenance are periodic costs that can strain financial resources.

2.5.6.2 Reskilling Needs and Workforce Displacement

Automation causes job displacement when machines replace humans in repetitive, routine tasks. The replacement poses severe difficulties for workers, particularly in sectors such as manufacturing, where job functions may become obsolete. Programs for reskilling and upskilling displaced people are vital for their transition into new roles; however, they are highly resource-intensive to implement on a large scale (World Economic Forum, 2021).

2.5.6.3 Complexity of Technology

Advanced automation technologies, such as AI and robotics, require specialised knowledge in design, implementation, and maintenance. In many firms, internal knowledge needed for the successful deployment and maintenance of such technologies is absent. The deficiency in this understanding might be at the root of inefficiency and the limited potential to exploit all the benefits of automation (IEEE, 2019).

2.5.6.4 Integration Issues

Integrating new automation technology with existing systems and processes is often cumbersome and time-consuming. Delays, increased costs, and heavy reengineering result from the inability of old infrastructure to support modern automation systems (PwC, 2022).

2.5.6.5 Cybersecurity Risks

Automation systems are increasingly susceptible to attacks as they rely more on connectivity and the Internet of Things (IoT). Significant threats arise from hacking, malware, and data breaches, especially in vital industries such as manufacturing, energy, and healthcare. Strong cybersecurity safeguards are crucial, but they often increase the complexity and cost of automation (Deloitte, 2021).

2.5.6.6 Regulatory and Compliance Issues

The rapid pace of development of automation technologies relative to legal frameworks naturally raises questions about their compliance. Such challenges in industries that manage labour laws, safety regulations, and data protection obligations may further delay the pace of adoption and increase costs (EU Digital Strategy, 2021).

2.5.6.7 Resistance to change

Employees and stakeholders frequently oppose the adoption of automation. While management may be reluctant to invest in new technologies, employees may struggle to adjust to new systems or fear losing their jobs. Overcoming this opposition requires establishing an accepting culture and proving the benefits of automation (Harvard Business Review, 2019).

2.6 Analysis of existing studies

The effects of Industry 4.0 (I4.0), as defined by the Fourth Industrial Revolution (4IR) and the Industry 4.0 concept, on the manufacturing industry in South Africa. A new method is used to examine the manufacturing sector in South Africa, which comprises about 11,400 VAT-registered businesses (Ngepah, et al., 2024). The study focused on the impact of Industry 4.0 on the manufacturing sector. To account for both stationary and nonstationary variables without recalculating the order of integration, the autoregressive distributed lag (ARDL) model was used in this study. Endogeneity, serial correlation, small-sample bias, and heterogeneity were all considered when estimating the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) models. Carbon dioxide emissions, manufacturing value added (MVA), I4.0, foreign direct investments (FDI), inflation, and other long-term correlations between factors were also accounted for. Although the Cumulative Dynamic Multiplier (CDM) graphically depicted impact correlations, Vector Autoregressive (VECM) modelling was utilised to establish causality linkages. Information from the World Bank's WDI (2023) for the 2000Q1–2020Q4 timeframe is working. One of their main conclusions was that there was a substantial inverse link between I4.0 and MVA in South Africa. Their study indicated that the policy implications recommended massive investments in higher education, information and communications technology, and medium- to high-tech exploration. Their study also found a long-run relationship between inflation and MVA, substantial short- and long-run impacts of foreign direct investment on MVA, and favourable correlations between carbon dioxide and MVA. These factors were insightful to consider when making strategic investment and policy decisions in light of technology improvements (Ngepah, et al., 2024). The study provides insightful data on the impact of the fourth industrial Revolution (4IR) on manufacturing in South Africa. It, however, does not study the direct effect on productivity in the South African manufacturing industry. It is also essential to explore analyses of other first-world countries on similar studies to measure or provide a baseline for this study.

The adoption of ICT and robotic automation systems in the pharmaceutical industry: a study by Moodley and James (South African Journal of Information Management). They focused on the adoption of ICT and robotics automation in the pharmaceutical industry. Their study was undertaken to review existing practice and encourage the integration of IT and Automated Storage and Retrieval Systems in retail and hospital pharmacies. Hence, IT and robotic automation in South African pharmaceutical dispensing were reviewed. This was a quantitative study that aimed to gather information from personnel working in hospital pharmacies, public and private, to identify users' needs and expectations; it analysed possible improvements resulting from the implementation of a new system. According to the study, automated dispensing systems were preferred by most South African government and private pharmacies to reduce errors, cut costs, improve inventory management, and enhance the customer experience. Reducing pharmaceutical errors, increasing operational effectiveness, and guaranteeing patient safety were further advantages. This research highlighted the need to integrate robotic automation and IT in the pharmaceutical industry to address existing problems. It shows the potential of automated robotic systems to minimise drug distribution errors and the factors that contribute to such failures. The study offered a roadmap for the revolutionary integration of robotic automation systems and information technology in South African pharmacies, highlighting the need for clearly defined regulations prior to deployment and guiding future implementation strategies.

Addressing the Impact of Fourth Industrial Revolution on South African Manufacturing Small and Medium Enterprises (SMEs). A study by Serumaga-Zake and van der Poll (2021) was conducted to assess the impact of 4IR on South African manufacturing SME. This study aimed to fill a gap by proposing a conceptual 4IR framework to help South African manufacturing SMEs overcome some of the challenges identified. A set of quantitative propositions, as our tool for creating a conceptual framework for integrating 4IR technologies and opportunities in the manufacturing sector, is defined through a thorough literature review followed by an explanation of the components of the 4IR and the difficulties facing the sector. Businesses can achieve continuous performance and competitiveness by leveraging the other elements of the framework. Further research in the area will determine the framework among players in the manufacturing industry in developing economies. This study was comprehensive and identified the elements SMEs can explore to improve their operational excellence. It, however, does not provide operational-level data analysis that can be used to identify inefficiencies that 4IR can address.

In exploring the global spectrum, Haleem *et al*. (2021a) conducted a study titled "Hyper-automation for the enhancement of automation in industries". In their study, they explore the concept of Hyper-automation, which, like this study, aims to enhance the traditional automation concept. This study briefly describes the need for hyper-automation in the modern world, then elaborates on the important roles' sensors play in amplifying it. Several agile technologies are included here, such as specialised workflow procedures, specific regions of solicitations regarding Diagrammatic discussions on hyper-automation. Further, in their paper, they identified and discussed the capabilities of hyper-automation for industries. Nowadays, in industries, it is observed that, with hyper-automation, significant improvements in the human element and the efficiency of automated activities are expected. It includes several automated technologies, which are sophisticated automation components, analytics, design, measurement, and monitoring. It is therefore best used to incorporate state-of-the-art equipment and develop new ways of working. Automation and cutting-edge technologies, such as artificial intelligence, are combined to solve complex problems and streamline processes. They have concluded that hyper-automation may unite people as technology and people collaborate side by side. It uses technology to analyse large datasets and apply the findings to its policymaking; hyper-automation transforms businesses by streamlining corporate procedures, eliminating repetitive tasks, and automating manual ones. It allows businesses to work quickly, accurately, and consistently. The concept is relevant and applicable to the current study of enhancing automation. Their study, however, did not focus on a specific industry such as manufacturing (Haleem, *et al*., 2021b).

The above studies capitalised on Industry 4.0, highlighting a gap and an opportunity to be explicitly explored to improve traditional methods such as standard automation. This gap can be used to enhance systems. This can be achieved by embracing modern technologies such as the Internet of Things (IoT), Machine Learning, and Digitisation systems, to mention a few. Industries stand to benefit significantly from such an implementation. However, it is worth acknowledging that the manufacturing industry should be the key focus, as it has adopted the traditional approach over several years. Even though adoption of automation has been widespread globally, South Africa, as a developing country, has adopted the traditional approach to automation to a certain extent, and it can also realise the benefits of further enhancing the automation already active in most of its manufacturing industries.

2.7 Theoretical Framework

Based on the reviewed literature and theoretical framework, the following hypotheses are formulated

- H_1: There is a statistically significant relationship between automation adoption and perceived productivity.
- H_2: External infrastructural factors moderate the relationship between automation adoption and perceived productivity.
- H_3: Automation adoption is significantly related to workforce morale.

CHAPTER 3 RESEARCH METHODOLOGY.

3.1 Introduction

Relative to the previous chapter, which outlined the theoretical aspect of the study. In this chapter, the method employed to conduct the study is outlined and further explored. The research design, methodology, sampling strategies, data collection, and analysis methodologies used in this study are presented in this methodology chapter. The study aims to explore the challenges and benefits of automation on productivity in the South African manufacturing sector, specifically focusing on a Germiston-based company that manufactures mining equipment. This chapter presents a comprehensive research methodology to ensure the validity, reliability, and reproducibility of the results.

3.2 Research Methodology

The science of conducting scientific studies is called research methodology. A methodical approach that employs a few logical processes to address the subject of the research. Methodology helps us make sense of both the outcomes and the processes of scientific research. Research methodology's objective is to describe and assess methods, clarify their resources and constraints, explicate their assumptions and deliverables, and relate their possibilities to the "frontiers of knowledge" grey area (Patel & Pate, 2019:48).

3.2.1 Research Paradigm

According to Lather (1986:89), a study paradigm naturally reflects the researcher's beliefs about the world and the world they aspire to inhabit. It comprises the fundamental concepts and beliefs that shape a researcher's viewpoint, understanding of the world, and actions within it. Scholars Guba and Lincoln (1994:105) described a paradigm as a basic collection of presumptions or worldviews that guide an investigation or research project.
The research paradigm employed in this study is positivist, which holds that reality is objective and quantifiable (Guba, & Lincoln, 1994). Positivism is based on the idea that

there is only one reality (ontology) and that studying phenomena requires objectivity and detached impartiality (epistemology) to discover this one reality. The positivist approach is experimental, challenges preconceived theories or hypotheses, and typically employs rigorous, quantitative research techniques with sizable sample sizes to objectively uncover this one reality (Oliver, 2010:75). The present study is appropriate for positivism since it emphasises quantifiable connections between automation (an independent variable) and productivity (a dependent variable) in an industrial setting. With this paradigm, the researcher can collect objective, verifiable facts and use statistical analysis to identify cause-and-effect relationships.

3.2.2 Research Approach and Design

To test theories about how automation affects productivity, a quantitative research approach was used, concentrating on the gathering and analysis of numerical data (Leavy, 2023). This methodology guarantees impartiality and permits reproducible results. It examines the association between automation level and productivity measures without manipulating any variables; the research design is correlational. The design is ideal for quantitatively linking naturally occurring departmental variation in automation adoption to productivity results.

Despite the use of advanced multivariate methods such as Structural Equation Modelling (SEM) in automation and productivity-related research, these methods have generally required larger sample sizes and construct validation, including confirmatory factor analysis. Considering the sample size to be 169 respondents, it was not methodologically possible to use SEM due to the exploratory nature of the research. However, correlation analysis offered a sound methodology to address the research questions without exposing the research to potential model overfitting and imprecise parameter estimation. This is consistent with established quantitative research practices.

3.2.3 Population, Sample, and Sampling Techniques

The study population consists of employees of a large manufacturing company in Germiston that specialises in the production of heavy mining equipment. The company employs about 500 people in different production departments. To reduce sample bias and to ensure that each eligible participant had the same probability of being selected, a random sampling technique was adopted. At a 95% confidence level and a 5% margin of error, 200 respondents were the targeted sample size. This sample size is reasonable for collecting data while ensuring viable statistical analysis.

3.2.4 Recruitment and Informed Consent

Emails, staff meetings, and training sessions were among the internal communication channels used to attract the participants. An informed consent form outlining the study's objectives, design, confidentiality protocols, and withdrawal requirements was given to each respondent, who was to consent to it. This was incorporated into the developed Google Form, which was presented to the participants. The ethical precepts of beneficence, fairness, and autonomy were rigorously upheld (Mandal & Subhash, 2014).

3.2.5 Data Collection Techniques

The study followed a quantitative approach, in which a primary data collection tool (questionnaire) was developed and distributed via various channels (email, QR codes, and mobile phones). A questionnaire is a form consisting of a set of questions and response options that respondents (representing a specific demographic) complete to enable the researcher to collect the information needed for a research study. It is not possible to collect information revealed by a questionnaire from secondary sources (Pandey & Pandey, 2015:57).

The questionnaire consisted of five parts: Section A: Demographic data. Section B: Perceptions of the level of automation. Section C: Productivity indicators (e.g., rate of output, reduction in errors, and downtime). Section D: External factors that affect automation and productivity. Section E: Open-ended questions to elicit more information. Most of the questions used a four-point Likert scale to measure attitudes and perceptions, ensuring the data were suitable for statistical analysis, while the open-ended section provided contextual data.

The questionnaire was designed in such a way that all the research variables, objectives of the study and statistical analysis were aligned directly. Multi-item Likert-scale questions were used to measure all core variables and, as such, composite scale scores could be computed.

- **Automation Adoption**:

This is assessed based on the questions under Section B of the questionnaire, with focus on the level of exposure, understanding, and interaction with automation systems by the respondents in their respective departments, including the level of integration, reliability, and utilization of such systems.

- **Perceived Productivity**:

This can be assessed through the item(s) described in Section C, which measures the respondent's perception of operational efficiency, output consistency, reduction of downtime, and efficiency of processes within the work environment.

- **External Factors**:

Section D gauged contextual restrictions, including energy reliability, infrastructure constraint, digital access and support of organisations, which could be coverage of the relationship between automation and productivity.

- **Workforce Morale**:

Workforce morale was measured using specific Likert-scale questions that investigated job satisfaction, perceived job security, and perceptions of the change caused by automation.

Each construct was further broken down into composite scores that were obtained by summing the applicable items to allow homogeneous statistical comparison between the variables.

The participants were then provided with an initial prompt where they had to consent to willingly take part in the study. Following participation in the study, the data was downloaded from the Google Forms platform and underwent various verification and data cleaning steps.

3.2.6 Reliability, Validity, and Pre-Testing

Multi-item scales were employed to measure all relevant variables, thus increasing the reliability of the research instrument. Before data collection, scrutiny of the questionnaire was conducted to determine its clarity and relevance to the research objectives; a small group of respondents was employed in a pilot study to establish areas of ambiguous wording and to determine face validity.

3.2.7 Treatment of Open-Ended Responses

Several open-ended questions were included in the questionnaire to supplement the results obtained from the quantitative part. The responses to these questions were not subjected to any qualitative coding or thematic analysis; rather, a descriptive analysis was conducted to provide contextual background and explanatory details to support the results obtained from the quantitative part. This helped to ensure that the research maintained its original quantitative focus while offering a limited amount of qualitative clarification when required.

3.2.8 Data Analysis Techniques

The data were coded and analysed using SPSS software with the assistance of a statistical analyst. Among the statistical procedures applied were descriptive statistics to summarise demographic data. The direction and magnitude of the automation productivity relationship are examined by applying Pearson correlation analysis. Regression analysis is employed to determine the predictive impact of automation on productivity. The findings are verified through hypothesis testing at the 95% confidence level. These approaches provided reliable, sound information on how higher automation influences output.

In addition, inferential statistics, such as multiple regression analysis and structural equation modelling (SEM), were used to establish potential causal relationships among internal factors, external factors, automation levels, and productivity outcomes. The method is intended to find out the predictive relationships between variables and their strength and direction, which would extend the analysis beyond the descriptive and correlational findings.

3.2.9 Ethical Considerations

North-West University provided ethical clearance. Data was securely stored, and anonymised responses were used to maintain confidentiality. The study only included volunteers who had been appropriately informed of its risks and objectives. The study protected participants by adhering to the principles of beneficence and non-maleficence.

3.2.10 Reliability and Validity

A small sample of employees participated in a pilot test of the questionnaire to ensure it was valid and easy to understand. Content validity was achieved by comparing the questions to the automation and productivity body of knowledge. Triangulation was provided, and the overall validity of the findings was increased by analysing both quantitative Likert-scale answers and qualitative open-ended comments.

CHAPTER 4 RESULTS AND DISCUSSION

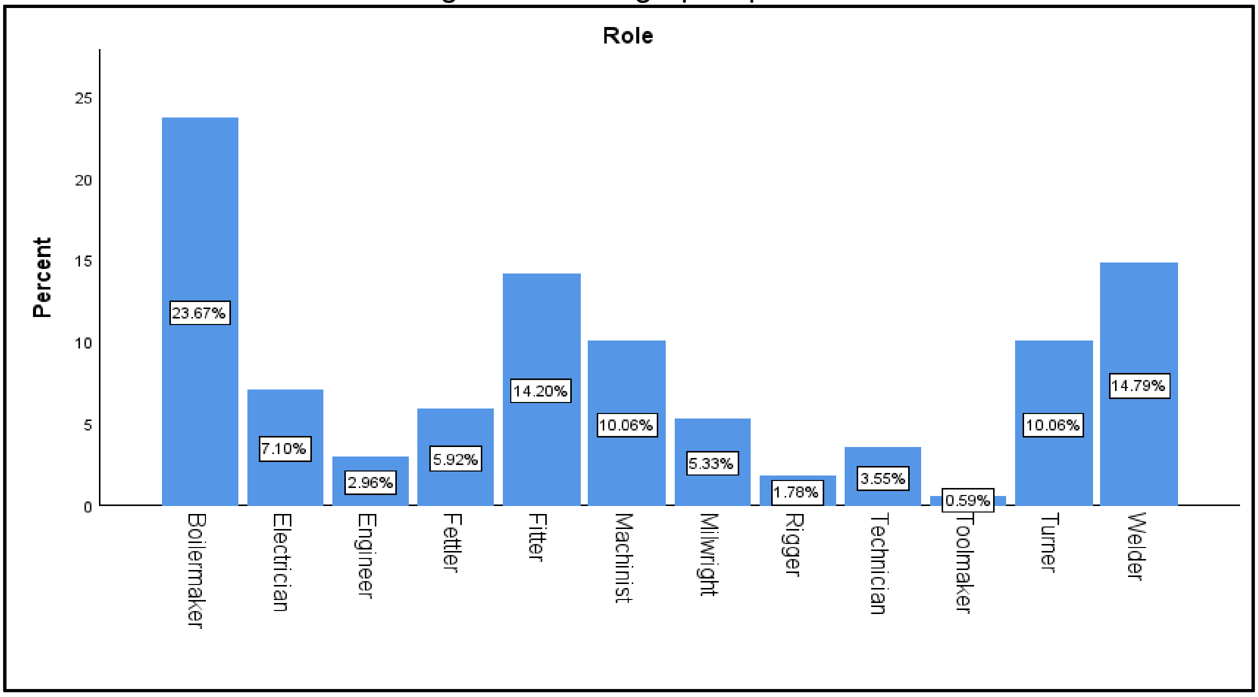
4.1 Introduction

This chapter presents the results of the study by summarising the demographic data of the respondents, reporting the frequencies of the main constructs, and assessing the relationships among automation, productivity, and external variables within the manufacturing environment. The composite scale scores, correlation analysis, and open-ended responses are also provided in the chapter so that one can have a holistic picture of how automation is perceived in terms of its impact on operations and on the morale of the workforce. It is the synthesis of these results that provides a holistic picture of the findings considered in the discussion and interpretation of the following chapter.

4.2 Results

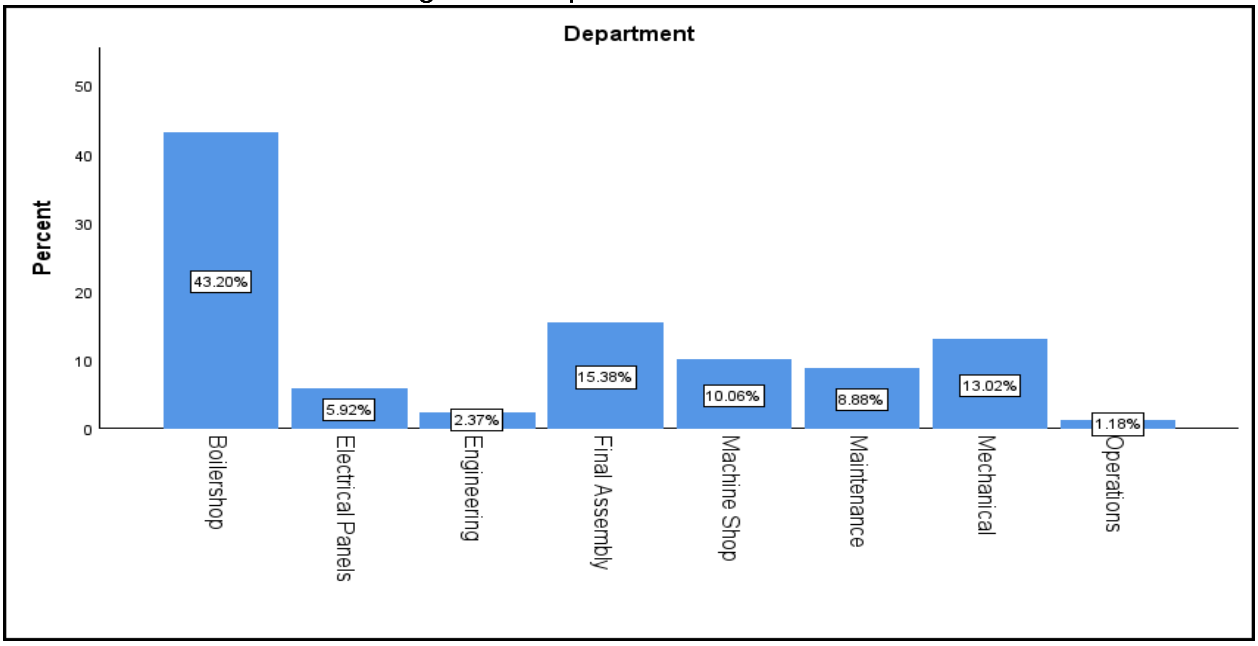
4.2.1 Demographic profile

Figure 5: Demographic profile



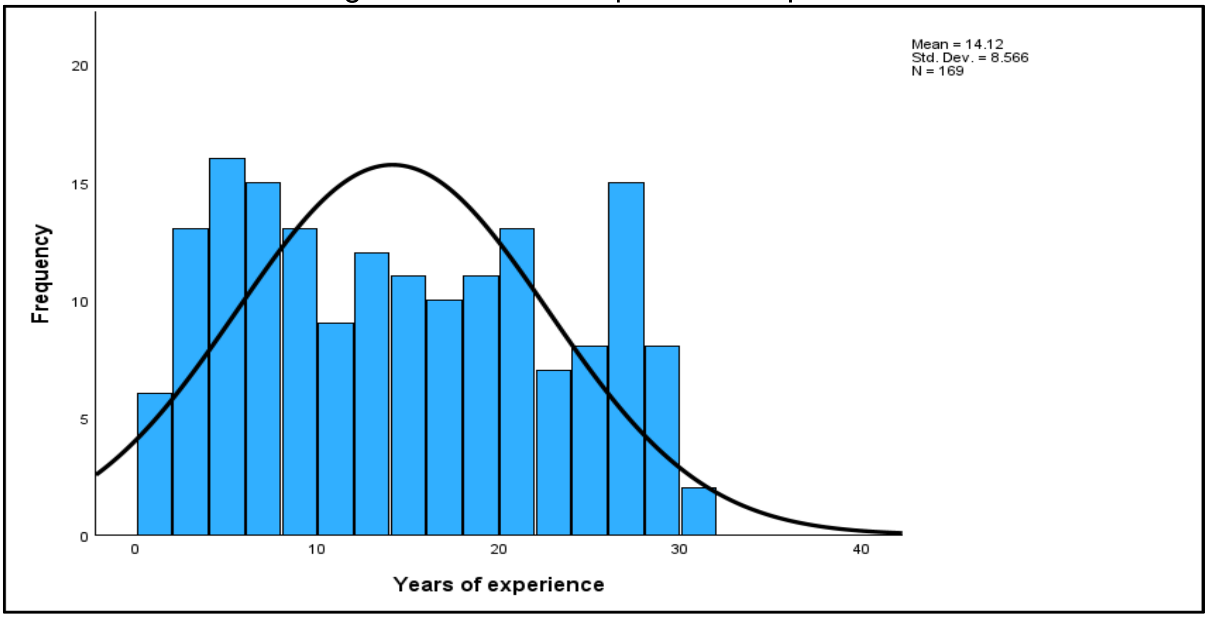
As per the above graph,169 out of the 200 targeted respondents participated in the study. The spread of roles was good, with boilermakers (23.7, n = 40) as the next-largest group, followed by welders (14.8, n = 25), and finally fitters (14.2, n = 24). The samples of machinists and turners were 10.1 (n =17) each. Electricians (7.1), fitters (5.9), millwrights (5.3), technicians (3.6), engineers (3.0), riggers (1.8), and toolmakers (0.6) had lower percentages.

Figure 6: Department distribution



The Boiler shop was the largest single department (43.2%, n = 73), followed by Final Assembly (15.4%, n = 26) and Mechanical (13.0%, n = 22). The other respondents were evenly distributed across the Machine Shop (10.1%), Maintenance (8.9%), Electrical Panels (5.9%), Engineering (2.4%), and Operations (1.2%).

Figure 7: Years of experience dispersion



	Minimum	Maximum	Mean	Std. Deviation
Years of experience	1	30	14.12	8.566

The number of years served ranged from 1 to 30, with a mean of 14.12 and a standard deviation of 8.57, suggesting that both young and old employees were present in the sample.

4.2.2 Descriptive results

4.2.2.1 Understanding and adoption of automation

The comparison of the respondents also shows that most respondents have experience with automation, with nearly half indicating medium experience (47.9%, n = 81) and 27.2% (n = 46) indicating high experience. However, 23.1 (n = 39) said they were not aware of any automation, and a few (1.8, n = 3) could not comprehend the question. Regarding automation adoption, 39.1% (n = 66) reported partial adoption, and 19.5% (n

= 33) reported broad adoption. Many of the respondents said they had adopted automation to a very little degree (minimal adoption, to a certain extent / very little, 27.2%, n = 46), and 7.1% (n = 12) had not adopted at all, and 7.1% (n = 12) did not know. The same trend was followed in the utilisation of robotics and automatic detection sensors, with responses being spread out, not yet, to a certain extent, partially and extensively, without a specific low or high adoption curve between the two technologies in various departments. Interestingly, the responses to disruption resulting from automation systems showed that several respondents thought sensors and other systems disrupted to some extent (not yet or very little), rather than those who thought the disruption was extensive.

4.2.2.2 Automation adoption scale

Regarding the large-scale adoption of automation in the business unit, most (92.9%, n=157) answered 'no automation,' and a small proportion (7.1%, n=12) said they did not know. This one seems to be, to some degree, incompatible with the more subtle answers to the previous automation items, and this incompatibility will be discussed later in the chapter.

4.2.2.3 Understanding and measurement of productivity

Regarding productivity, 50.9% (n = 86) of the respondents had medium knowledge, 30.8% (n = 52) had high knowledge, and 17.8% (n = 30) had no knowledge. The percentage of those who did not comprehend the question was only 0.6 (n=1).
In terms of productivity within the department, most respondents (42.6, n = 72) measured productivity partially, with a smaller proportion measuring it extensively (26.0, n = 44), and smaller proportions measuring it limitedly, not measuring it, or not knowing.

An identical pattern appeared with the critical assessment of productivity measures (Q13) and its use of formal measures like OEE and OTD to a certain extent (Q14): the responses were distributed over the entire range of choices, with the general inclination towards the answers of to a certain extent and partially, which suggests that the measurement and evaluation practices are already in existence but might not be fully developed and uniformly used.

Regarding perceived productivity levels (Q15), respondents were relatively positive: 44.4% (n=75) excellent, 39.1% (n=66) average, and 14.2% (n=24) low.

4.2.2.4 Understanding and measurement of productivity

The majority of respondents on the perception of external factors have alluded that the impact of external factors on automation is minimal. A significant number of responses were chosen as very little or partially, with less substantial proportions about extensively, and missing (or don't know) in some questions. That implies that external disruptions exist but are not uniformly experienced in all the departments.

4.2.3 Scale Scores for Automation, Perceived Productivity and External Factors

Three important constructs were measured using composite scales: Automation, Perceived Productivity, and External Factors. These scales did not include items related to respondents' cognitive understanding of the constructs. The 'don't know' response was marked as missing and thus excluded from the computation of the scale. Consequently, the scale scores ranged from 1 to 4, with 4 indicating high levels of the construct.

Table 1:Automation scale score

Scale	***Minimum***	***Maximum***	***Mean***	***Std. Deviation***
Automation	1.40	3.50	2.47	0.39
Perceived productivity	1.60	3.80	2.87	0.41
External factors	2.00	4.00	2.83	0.41

Automation scale scores ranged from 1.40 to 3.50 (M = 2.47), and Perceived Productivity scores ranged from 1.60 to 3.80 (M = 2.87). The external Factors scored between 2.00 and 4.00 (M = 2.83). Overall, the average score was in the middle of the scale (2.5), and there were no strong odds towards very high or very low scores. The trend aligns with the frequency of items, indicating that respondents used the full range of responses.

4.2.4 Correlations Between Key Variables

The scale variables were checked for normality before the correlation analysis. The skewness ranged from -0.068 to 0.424, within the range of -1 to +1, indicating that the data were normally distributed and that the Pearson correlation was suitable (Hair et al., 2022:10).

	Automation	**Perceived productivity**	**External factors**
Automation	–		
Perceived productivity	0.033	–	
External factors	0.133	0.015	–

Table 2: Correlations between key variables

None of the correlations between the composite scales were statistically significant (all $p > 0.05$). That is, there were no significant correlations between perceived productivity, automation, and external factors in the given sample, as initially anticipated: an increase in automation or external interference would not correlate with changes in productivity. The unexpected outcome needs to be discussed in the following discussion chapter, where possible explanations, including the wording of the items, the operationalisation of the constructs, or the influence of the circumstances, might be critically questioned.

Though the inferential techniques like multiple regression and structural equation modelling were intended to be used to test the causal relationship, the creation of statistically insignificant correlation between major variables rendered them inapplicable. This conclusion is rather informative, meaning that external factors might not have a direct bearing on productivity in the sample under consideration, and thus, informs a more sophisticated approach to interpreting the results.

4.2.5 Relationship Between Years of Service and Understanding of Automation

The level of understanding of automation was also assessed by asking respondents to indicate their level of understanding. Since this variable is ordinal, the correlation between years of experience and knowledge of automation was analysed using Spearman's rho. The findings showed no statistically significant correlation between years of experience and self-reported analysis of automation ($p > 0.05$). In this way, the longer the tenure in the organisation, the less likely it is that the reported overview of automation concepts will be high.

4.2.6 Relationship Between Years of Service and Understanding of Automation

The respondents were allowed to select a variety of technologies applied within their departments (multiple-response question). Respondents hence computed percentages rather than responses, since this is more intuitive when respondents can select more than one category. The findings show that:

- 32.5 per cent of the respondents indicated that they used the Internet of Things (IoT).
- 30.8% reported using cloud computing.
- 29.6% reported using Robotics.
- 28.4% said that they had used Artificial intelligence.

These were the most common technologies that were used. A smaller percentage of respondents used other forms of automation (e.g., CNC/Variable Speed Drives, PLCs/SCADA, Vision Systems), and 10.7% said they do not use any technology.

4.2.7 Relationship Between Years of Service and Understanding of Automation

The technology categories were recoded to include only those with sufficient samples (N > 10) to investigate the relationship between the type of technology used and the extent of automation adoption. These were cross-tabulated with the level of automation (e.g. less than half of the process automated; greater than that and less than 80%). Due to small values on the lowest and highest levels of automation, one is led to interpret the mean categories. In general, the findings reveal that the majority of respondents reported that their companies are either half-automated or 80% automated. Under the less than 50% segment, 33.3% of the respondents answered Cloud computing, 33.3% answered the Internet of Things, and 35.1% answered Robotics. In the 50-80 per cent automation category, 34.6 per cent was Artificial intelligence, 40.4 per cent was the Internet of Things, and 26.9 per cent was Cloud computing. These trends indicate that as automation scales into the partial to moderate range (50-80%), more sophisticated technologies, including Artificial intelligence and IoT, are increasingly reported, whereas Cloud computing and Robotics are significant at various levels of automation.

4.2.8 Impact of Automation on Production Efficiency

Overall, the respondents' opinions on the impact of automation on production efficiency showed mostly positive aspects, such as improved consistency, reduced idle time, shorter cycle times, increased machine usage, and standardised quality through reduced human error. Automation was also perceived as useful for enhancing accuracy and traceability, as well as for reducing rework or scrap. Also, workers valued that automation lowers the high rates of manual labour and repetitive efforts and enables teams to work on more value-added projects. Nonetheless, specific issues were raised, e.g., production-related delays such as line blockages, lack of flexibility, and compatibility with older equipment.

Other issues raised by the respondents include greater reliance on electricity, networks, technical support, and specialised maintenance knowledge. Some of the challenges related to human beings involved stress during transition phases, systems that had to be continuously monitored, and training requirements. Although these issues were noted, the general mood was good as respondents noted the massive operational changes brought about by automation.

4.2.9 Impact of Automation on Workforce Morale

The majority of the respondents cited more positive than negative impacts of automation on the workforce. On the one hand, employees, particularly young or technologically oriented workers, were motivated and proud to be employed in a modernising, technology-driven environment. Automation was reported to enhance job satisfaction because it reduced routine and physical strain, increased confidence when operations ran smoothly, and enhanced team spirit through shared learning and training. It also encourages innovation and inter-team problem-solving. Nevertheless, various issues were also raised: automation can lead to anxiety about job security, reveal skill deficits, and provoke short-term mood swings during implementation or training. Digital tools can be challenging for some employees, and they may be resistant to change or frustrated by system breakdowns. Such factors may cause varying morale, attitude change and indecisiveness. Despite this, the respondents reported that favourable morale outcomes tend to prevail over unfavourable ones, especially when organisations articulate their vision effectively and assist employees with the transition.

4.3 Result Discussion

The results of this analysis were mainly based on descriptive statistical analysis. The study was conducted to investigate patterns, trends, as well as general perceptions on automation, productivity, and competitiveness in the manufacturing industry. The descriptive findings demonstrated evident differences in the way automation is adopted and received within departments, which means that the general attitude to automation is positive, but its effects in different operational situations and resource levels are different. These findings provided the overall picture of the manufacturing environment, which enabled interpreting the impact of automation on productivity at a realistic level without the need to presuppose causality.

Although the use of inferential statistical methods, including multiple regression and structural equation modelling, was initially intended to test the possible causal relationship, the results revealed that the relationship between the key variables was not statistically significant. The inferential methods became a secondary layer of analysis which was mainly used to support the patterns that were found in the descriptive analysis, but not to make causal inferences. This finding is critical as it justifies the choice to depend on descriptive statistics to make sense of the information. It also highlights the intricacy of the correlation between automation and productivity, indicating that the dynamics can be subject to a variety of external and organisational influences that cannot be well represented using quantitative inference. In this way, the focus on descriptive analysis not only promotes the empirical validity of the study but also ensures that the interpretation of the findings is consistent with the facts of industrial automation and performance improvement.

4.4 Summary

The data distribution indicated that most of the respondents were personnel of the boiler shop which is one of the main production units in the organisation. This section is the key point of fabrication and assembly but not very automated as other parts of the operations like machining, assembly, and testing. The boiler shop is extremely dependent on manual operations, including welding, fitting and heavy fabrication, thus restricting access to new technologies of automation. Such disparity in the level of automation is a critical contextual consideration that may have affected the observed outcomes and possibly led to the lack of statistically significant relationships between automation-related constructs and productivity indicators.

The culture of the boiler shop will also not be exactly the same as in other departments that are more technologically driven. Employees in this department might feel that automation is not an imminent or progressive change, but a part of their daily work and thus their reactions would be more cautious or conservative. ANOVA (Analysis of Variance) tests were conducted to test the possibility of the differences in perceptions between different departments. The findings however showed that the responses in different work areas and other demographic groupings showed no statistically significant differentiation. This observation supports the argument that the general pattern of response is a collective organisational feeling, and it is not based on the experience within the department itself. This is why elaborate results of ANOVA are not presented in the body of the text; however, in this section, it is recognised to indicate analytical rigour and transparency of interpreting the quantitative results.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The objective of the study was to analyse the advantages and issues of automation within a manufacturing company that deals with heavy mining machinery, with particular focus on the effects of automation on productivity, operational efficiency, and workforce morale. The chapter consolidates the major findings of Chapter 4. It explains how these findings relate to the theoretical arguments developed in the previous chapters, along with recommendations for management and future studies. It will help the company align with its strategic direction by strengthening the integration of automation, productivity, and staff development.

5.2 Conclusion and Achievement of the Study Objectives

The primary objective of the study was to investigate the relationship between automation and productivity in a manufacturing setting in South Africa, and to determine how employees understand the factors that determine productivity levels. This general goal was complemented by the secondary objectives, which are:

- To examine the level of automation adoption within the organisation.
- To determine the extent to which automation influences perceived productivity.
- To identify external factors influencing automation and output.
- To explore employees' understanding and experience of automation.
- To assess how automation impacts workforce morale.

5.2.1 Achievement of Objectives

Objective 1: Automation Adoption Levels

The results indicate heterogeneous adoption of automation across departments, with most respondents reporting partial or limited adoption, and a large minority reporting medium or high exposure. The most popular technologies are as follows: IoT (32.5 per cent), cloud computing (30.8 per cent), robotics (29.6 per cent), and artificial intelligence (28.4 per cent). These findings confirm that automation is present, but there are considerable differences in automation levels across units, suggesting an unequal profile of digital maturity across the organisation.

Objective 2: Influence of Automation on Productivity

In contrast to the theoretical anticipation and most of the literature available, which tend to assume a positive correlation between automation and productivity, the findings of this study showed that there is no statistically significant correlation between automation and perceived productivity, or between automation and external factors ($p > 0.05$). This result shows that the existing level and type of automation are not necessarily the main factor of productivity results in the studied organisation. It indicates that the current level of automation may not be the main determinant of productivity outcomes, but rather that factors within the organisation may influence them, including inconsistent system use, irregular processes within the department, or the absence of alignment between technology and operational strategy.

This outcome might have several reasons. The first being the level of automation in the departments not being balanced with some department, including the boiler shop, still being highly manual and labour intensive. Second, non-regular usage of systems and non-uniform processes of different departments could have restrained the proper use of technology. Third, the mismatch of technological projects and operational strategy could have diminished the potential benefits of automation. Also, organisational culture and workforce readiness might have played a role in how employees viewed automation to mitigate the visible effect on productivity.

This finding is very crucial since it negates the belief that automation would necessarily increase productivity. It highlights the significance of exploring the interaction of the contextual, cultural, and managerial variables with technology in impacting performance. It is therefore suggested that future researchers should consider qualitative in nature, e.g., using interviews, focus groups, or case studies to determine what employees experience of automation and the reasons as to why the statistical relationship is weak in this research. These qualitative observations may be used to augment the quantitative results and help to create a more sophisticated view on the role of automation in the formation of productivity in South African manufacturing contexts.

Objective 3: Understanding of Automation and Workforce Experience

The correlations were found to be non-significant ($p > 0.05$); that is, the year of experience and the comprehension of the employees with automation did not correlate (Spearman rho). It means that automation knowledge is not correlated with years of experience but rather is likely to be associated with training exposure, departmental practices, or competence development.

Objective 4: External Factors Affecting Automation and Productivity

Quantitative relationships found between automation and productivity, when scaled with external factors (infrastructure reliability, consumption, training, complex integration, and system disruptions), indicated no correlation. Nonetheless, qualitative rich responses indicated perceptions of system downtime, the network's interdependence, resistance to change, and training deficiencies as key factors that limited productivity.

Objective 5: Impact of Automation on Workforce Morale

Morale is affected by automation, as understood through open-ended responses, in both positive and negative ways, but is primarily positive. Workers valued productivity improvements, reduced physical workload, and opportunities to develop skills. On the other hand, the fear of job insecurity, the stress of adaptation, and frustration with technical interruptions were also concerns.

5.3 Discussion Of Findings

5.3.1 Linking Findings to Literature

Unlike the anticipation of increased productivity from automation, as has been demonstrated in the existing international literature, the findings do not show a statistical relationship. The cause of this divergence can be poor automation maturity in departments, unstandardised workflows which caused the variability of the outputs, failure to integrate human operators and machines fully, measurement issues, because perceived productivity is not necessarily related to objective output measurements and limitations associated with the design of the questionnaires referred to in the commentary of the document where the phrasing could have limited the sensitivity of measure. However, open questions data/responses agree with the global studies. The respondents identified the potential to use automation to reduce mistakes, increase cycle speed, and improve work quality, which aligns with the productivity literature described in the previous chapters.

5.3.2 Interpretation of Non-Significant Relationships

The lack of correlation between automation and productivity implies that Automation is still not sufficiently developed to achieve quantifiable productivity improvements. Productivity improvements can be latent, and systems need time to level off. Employees tend to misunderstand productivity and focus on their hard work rather than productivity.

External factors such as power failures, system failures, and maintenance capacity can mediate or suppress productivity gains.

5.3.3 Workforce Morale and Skills Transition

The results regarding workforce morale are consistent with the current literature on change management: the more an employee is properly trained and supported, the more they can accept automation, which can lead to fear and resistance when the changes are not understood. Employees who appear younger seem more flexible, according to the technology-adoption theory.

5.4 Recommendations

Despite the lack of statistically significant evidence on the relationship between automation and productivity, or perceptions of workforce in the quantitative analysis. The literature review and contextual results establish practical steps that may enhance automation results in the same manufacturing context. Hence, the recommendations listed below are mainly explained by theory rather than proven quantitative fact:

5.4.1 Improve Automation Integration

- Previous research had identified the significance of system-level integration as a factor accelerating productivity improvement; the company would be encouraged to optimise the ability of the automation system to interact across the different departments.
- Automate interdepartmental processes to enhance adoption across departments.
- Attention should be given to departments that are having lower maturity of automation, as broader adoption is often associated with operational stability and quality improvements (Mehta, *et al.*, 2018:4).

5.4.2 Enhance Training and Competency

- There is always an association by literature of the workforce readiness and digital literacy with the successful automation adoption. As such, continuous development of digital skills must be a priority with the emphasis on the changes in technologies that are applicable in the operations of the company. Practical training for operators who use automation equipment, such as robotics and other types of automation should be carried out.

- Operators who would work with robotic systems and programmable ones should be provided with practical training to enhance competence and ease the resistance to change.

- Knowledge should be institutionalised as strategies to retain and document automation expertise to reduce the losses incurred due to loss of knowledge and maintain operational excellence.

5.4.3 Strengthen Organisational Support Systems

- The literature focuses on the fact that the success of automation is reliant on strong support frameworks, including predictive maintenance and IT reliability (Dalenogare, et al., 2018:23). Increase and improve IT system support for cloud-based systems, such as IoT, to ensure seamless operation during manufacturing.

- Develop a formal change-management model which will assist in the management of the transition when upgrading the technology, enhancing the level of engagement and acceptance among the workers.

5.4.4 Re-align Productivity Measurement

- As much as the study did not empirically support the correlation between automation and productivity, the objective indicators such as the OEE, cycle time and rate of defects remain critical in measuring technology efficiency. Real-time indicating dashboards are to be incorporated into current systems to combine machine data that can be visualised in real time.

- KPI systems need to be restructured to match a perception of employees' performance and operational measures that may be performed in past productivity models.

5.5 Limitations of the study

The following limitations are to be outlined as per the outcomes of the study:

Subjective perceptions, which are prone to bias are employed in this study.

- Limited scope and single focus on organisations, which minimise generalisability in the study.
- Non-significant correlations, which reduce the explanatory power of statistical analysis.
- Potential measurement limitation in the phrasing of the questionnaire.
- Depending on the level of automation across departments, it's hard to compare.

5.6 Recommendations For Future Research

The empirical investigation failed to demonstrate statistically significant links between automation and perceived productivity, as a result, future studies should develop on the weaknesses and strengths of this study in gaining a better insight into the effects of automation on organisations. The subsequent recommendations can therefore be made to enhance investigations in this area in the future:

- The future research needs to be implemented as mixed-methods research that would combine both quantitative performance data and qualitative employee and management-based data. Although the current research followed a subjective perception obtained with the help of structured questionnaires, supplementing them with objective operation measurements, i.e., the Overall Equipment Effectiveness (OEE), downtime, throughput, and defect rates, would help increase the validity as well as explanatory power of findings.

- The second important suggestion is to expand the sample base to a wider sample, which should be a single manufacturing organisation. An inter-regional or cross-sector analysis that incorporates a variety of manufacturing sub-sectors (e.g., automotive, mining equipment, electronics, and food processing) would also offer a relative vision of the state of automation and its consequences. Focus on studying the longitudinal effect of automation as systems continue to mature.

- The adoption of automation is a dynamic process, longitudinal designs should be popularised in future because they allow tracking of the performances and changes in behaviour. The data provided in the study is cross-sectional and therefore can only reflect the perceptions at one time. Longitudinal research, in turn, would be able to monitor the development of automation benefits (e.g., increased efficiency, work quality, and flexibility of the workforce) as technology has grown and experiences have accumulated on the part of the employees.

- As the development of skills and the interaction of humans and computers are the research areas of the future, the instances of automation are thus impacting the job roles. The research questions can address the impact of digital literacy skills and the flexibility of the employee in the technological environment on productivity.

5.7 Chapter summary

This chapter summarised the key findings, put them within the scope of the research goals, connected them with the literature and developed recommendations. The organisation's adoption of automation is increasing, but there is no evidence of its impact on productivity due to the lack of training, system integration, and workflow standardisation. However, open questions results demonstrate definite possibilities for improving operational and morale benefits if the challenges in the implementation process are addressed. The reference list is given in the following chapter.

REFERENCES

Ahmad, T., Khan, Z. & Hassan, S., 2023. Understanding population and sampling in quantitative research. Journal of Social Research Methods, 12(3), pp.1–12.

Arunachalam, S. & Ghosh, S., 2021. Artificial intelligence: Foundations and future directions. *International Journal of AI Research*, 8(2), pp.45–59.

Bangura, J., 2024. Effective recruitment strategies for industrial research. *Journal of Organisational Management Studies*, 9(1), pp.40–54.

Britannica, 2025. Automation: Technology and applications. [online] Available at: <https://www.britannica.com/technology/automation> .Date of Access:20 Nov. .2025.

Cantore, N., Clara, M. & Soare, C., 2017. Manufacturing as a driver of economic growth. UNIDO Industrial Development Report. Vienna: United Nations Industrial Development Organization.

Codera Analytics, 2023. Automation adoption trends in emerging economies: South African manufacturing overview. Johannesburg: Codera Research.

Deloitte, 2021. Cybersecurity in the age of automation. Deloitte Insights Report. [online] Available at: <https://www.deloitte.com> .Date of Access:20 Nov. .2025.

Derby, M., 2023. Transport infrastructure bottlenecks in South Africa’s industrial logistics. Business Day, 15 August. [online] Available at: <https://www.businesslive.co.za> .Date of Access:20 Nov. .2025.

Ertel, W., 2025. Introduction to Artificial Intelligence. 3rd ed. Berlin: Springer.

EU Digital Strategy, 2021. Artificial Intelligence policy and regulatory frameworks in the European Union. Brussels: European Commission.

Groover, M.P., 2025. Automation, production systems, and computer-integrated manufacturing. 6th ed. Upper Saddle River, NJ: Pearson.

Guba, E.G. & Lincoln, Y.S., 1994. Competing paradigms in qualitative research. In Denzin, N.K. & Lincoln, Y.S. (eds.), Handbook of Qualitative Research. Thousand Oaks, CA: Sage Publications, pp.105–117.

Haleem, A., Javaid, M. & Khan, I.H., 2021. Hyper-automation for the enhancement of automation in industries. Journal of Industrial Engineering Research, 18(4), pp.1–14.

Harvard Business Review, 2019. How to overcome employee resistance to change. [online] Available at: <https://hbr.org> .Date of Access:20 Nov. .2025.

Hatzichronoglou, T., 1997. Revision of the high-technology sector and product classification. OECD Science, Technology and Industry Working Papers, 1997/02. Paris: OECD Publishing.

IDC, 2019. South Africa Manufacturing Report 2019. Johannesburg: Industrial Development Corporation.

IEA, 2021. South Africa 2021: Energy policy review. Paris: International Energy Agency.

ILO, 2025. World Employment and Social Outlook 2025: The Future of Work and Productivity. Geneva: International Labour Organization.

International Trade Administration (ITA), 2024. South Africa – Information and Communication Technology Overview. Washington, DC: U.S. Department of Commerce.

Jameel, S. & Majid, M.A., 2018. Ethical considerations in social research. International Journal of Research Ethics, 4(2), pp.77–84.

Komatsu, 2025. Komatsu South Africa Company Profile. [online] Available at: <https://www.komatsu.co.za> .Date of Access:20 Nov. .2025.

LabourNet, 2024. Labour relations trends in South African manufacturing. [online] Available at: <https://www.labournet.com> .Date of Access:20 Nov. .2025.

Lather, P., 1986. Issues of validity in openly ideological research: Between a rock and a soft place. Interchange, 17(4), pp.63–84.

Lean Enterprise Institute, 2025. Lean manufacturing principles and continuous improvement. [online] Available at: <https://www.lean.org> .Date of Access:20 Nov. .2025.

Leavy, P., 2023. Research Design: Quantitative, Qualitative, Mixed Methods, Arts-Based, and Community-Based Approaches. 3rd ed. New York: Guilford Press.

Mandal, J. & Parija, S., 2014. Obtaining informed consent in clinical research. Tropical Parasitology, 4(1), pp.78–80.

Modern Mining, 2024. Komatsu introduces new hard rock miner in South Africa. Modern Mining Journal, 6(2), pp.12–14.

Moodley, P. & James, T., 2024. The adoption of ICT and robotic automation in South African pharmaceutical dispensing. South African Journal of Information Management, 26(1), pp.45–62.

Ngepah, N., Thobeka, L. & Moyo, K., 2024. Industry 4.0 and manufacturing performance in South Africa: Evidence from ARDL and FMOLS models. Journal of Industrial Policy Studies, 15(2), pp.1–15.

Oliver, P., 2010. The student’s guide to research ethics. 2nd ed. Maidenhead: Open University Press.

Pandey, P. & Pandey, M., 2015. Research methodology: Tools and techniques. 3rd ed. New Delhi: Bridge Centre.

Patel, V. & Pate, M., 2019. Foundations of Research Methodology. New York: Academic Press.

PwC, 2022. Global automation readiness index 2022: Risks and resilience in the digital economy. PwC Report. [online] Available at: <https://www.pwc.com> .Date of Access:20 Nov. .2025.

Reuters, 2024. ArcelorMittal South Africa faces strike action over job cuts. Reuters Africa, 14 February. [online] Available at: <https://www.reuters.com> .Date of Access:20 Nov. .2025.

SAICE, 2022. Infrastructure Report Card for South Africa 2022. Midrand: South African Institution of Civil Engineering.

Serumaga-Zake, P. & van der Poll, H.M., 2021. The impact of 4IR on South African manufacturing SMEs: A conceptual framework for competitiveness. South African Journal of Business Management, 52(1), pp.60–77.

South African Government, 2024. Department of Water and Sanitation Annual Report 2023/24. Pretoria: Government Printer.

South African Government, 2025. Department of Transport Annual Report 2024/25. Pretoria: Government Printer.

Taherdoost, H., 2021. Data collection methods and instruments in research methodology. *International Journal of Academic Research in Management*, 10(2), pp.10–25.

The Reserve Bank of Australia, 2025. Productivity metrics and measurement frameworks 2025. Sydney: RBA Research Division.

U.S. Bureau of Labor Statistics, 2025. Productivity and costs – manufacturing sector report 2025. Washington, DC: U.S. Department of Labor.

World Bank Group, 2024. South Africa Economic Update 2024. Washington, DC: World Bank Publications.

World Bank Group, 2025. Global Productivity and Development Report 2025. Washington, DC: World Bank.

World Economic Forum, 2021. The Future of Jobs Report 2021. Geneva: WEF Publications.

World Economic Forum, 2023. Shaping the Future of Advanced Manufacturing and Production. Geneva: World Economic Forum.

ANNEXURES A: (PERMISSION LETTER)

KOMATSU

Komatsu Mining Corp
14 Commercial Road, Wadeville
1428, ZA
Phone: +2711 872 4000
Email: ksazamb_info@global.komatsu

Kuben Govender
Manager – Engineering (Process)
Manufacturing

5 February 2025

Dear Recipient

I **Kuben Govender** grants permission to **Khutso Nkogatse**, student number 40474593 at Northwest University to complete a study at Komatsu Mining on the topic:

The Effect of enhanced automation on the level of productivity in the South African manufacturing industry.

The study is to be conducted in an ethically considerate manner and take cognizance of the company IP protection policy.

The permission allows him to conduct questionnaire/interviews and gain access to manufacturing data which can be valuable to the study.

Khutso Nkogatse	Kuben Govender
....	05/02/2025

ANNEXURES A: (QUESTIONNAIRE)

Research study: Analysing the benefits and challenges of automation in a manufacturing company

Thank you for taking part in the research. I really appreciate it. You may stop at any time without negative consequences. Confidentiality and anonymity are guaranteed, and your questionnaire will be referred to by a number only. The demographic questions are simply to distinguish between the responses of different departments, levels, and experience levels and are not intended to profile participants. Please answer the following questions. The questionnaire will take approximately 15 minutes to complete.

<u>Section A: Demographics (Background):</u>

1. What is your current *role* within the organisation?

2. How many years' *experience* do you have in the manufacturing industry?

3. Which *department* do you primarily work in? (e.g., Operations, Engineering, IT, Logistics, Management)

4. Which of the following *technologies* are currently used in your operations? (Select all that apply)

    1. Robotics

    2. IoT (Internet of things)

3. Artificial intelligence

4. Cloud computing

5. Other automation (please name it: ………………...…………………………………….)

6. None

Section B: Automation:

5. My level of *understanding* of automation is:
    1. None
    2. Low
    3. Medium
    4. High
    5. I don't understand the question.

6. Has your department/business unit adopted any form of automation in its process?
    1. Not yet
    2. To a certain extent/very little
    3. Yes, partially
    4. Yes, extensively
    5. Don't know

7. The business unit makes use of *robotics* in the process:
    1. Not yet
    2. To a certain extent/very little
    3. Yes, partially
    4. Yes, extensively
    5. Don't know

8. Automation systems, such as automatic detection sensors, are being *used* on machines /equipment:

    1. Not yet
    2. To a certain extent/very little
    3. Yes, partially
    4. Yes, extensively
    5. Don’t know

9. The systems, such as automatic detection sensors, *disrupt or interrupt* the operation:

    1. Not yet
    2. To a certain extent/very little
    3. Yes, partially
    4. Yes, extensively
    5. Don’t know

10. What is the *scale of automation adoption* in your business unit/department?

    1. 0%-None (No automation)
    2. Less than 50% - Minimal (Small section of the process)
    3. More than 50% but less than 80% - Partial (Half of the process)
    4. 80 - 100% - Full scale (Overall process)
    5. Don’t know

Section C: Productivity:

11. My level of *understanding of productivity* is:

    1. None
    2. Low
    3. Medium
    4. High
    5. I don't understand the question.

12. Productivity is *measured* in our department or section:

    1. None
    2. To a certain extent/very little
    3. Yes, partially
    4. Yes, extensively
    5. Don't know

13. Productivity measures are *critically evaluated/analysed*:

    1. None
    2. To a certain extent/very little
    3. Yes, partially
    4. Yes, extensively
    5. Don't know

14. *Productivity measurements* such as OEE, OTD, etc, are being used in measuring productivity in the department:

1. None
2. To a certain extent/very little
3. Yes, partially
4. Yes, extensively
5. Don't know

15. How would you rate the *level of productivity* in the department?

1. Low
2. Average
3. Good
4. Excellent
5. Don't know

16. Automation directly *impacts* the level of productivity in the department.

1. It does not
2. Very little
3. Yes, partially

4. Yes, extensively

5. Don't know

Section D: Assessment of External Factors:

17. *External factors disrupt* operations/processes in the department:

1. It does not

2. Very little

3. Yes, partially

4. Yes, extensively

5. Don't know

18. The department's processes are impacted mainly by *unrest / employee relations*:

1. It does not

2. Very little

3. Yes, partially

4. Yes, extensively

5. Don't know

19. The department's processes are impacted mainly by *water disruptions*:

1. It does not
2. Very little
3. Yes, partially
4. Yes, extensively
5. Don't know

20. The department's processes are impacted mainly by *power outages*:

1. It does not
2. Very little
3. Yes, partially
4. Yes, extensively
5. Don't know

21. The department's processes are impacted mainly by *extreme weather conditions*:

1. It does not
2. Very little
3. Yes, partially
4. Yes, extensively
5. Don't know

22. *External factors directly affect productivity* in the department:

1. It does not
2. Very little
3. Yes, partially
4. Yes, extensively
5. Don't know

<u>Section E: Short answers:</u>

23. In your view, does technology such as automation positively or negatively affect the *production efficiency* in your department? Why do you say so?
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
……………………………………………………………………………

24. In your view, describe how automation affects workforce *morale* in your department. Why do you say so?
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
……………………………………………………………………………

I sincerely thank you for your participation. I hope this research will positively contribute to a positive workplace for you and us all.